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THE RECENT DYNAMITE DISASTER, SANTANDER, SPAIN.—*From The Graphic.*

THE SANTANDER DISASTER.

"TOWARD evening the sky was lurid with the reflection of unchecked and uncontrolled fires in various parts of the city. Mendez Nunez Street, which runs parallel with the quay, was ablaze from one end to the other, and the work of searching for, extricating from confused heaps, and identifying the dead was carried on amid this brilliant but awful illumination. Nobody attempted to cope with the conflagration, people were too panic stricken to think of anything but the safety of themselves and their families; so the fires raged all night, block after block of buildings being destroyed, until the whole street was burned out."—*The Graphic, London.*

TERRIBLE EFFECTS OF DYNAMITE.

THE seaport town of Santander, near Bilbao, on the north coast of Spain, was the scene of a terrible disaster on Nov. 3, causing the loss of between two and three hundred lives, with serious injuries also to several hundred other persons, and great destruction of property, including damage to many houses in the town. A Spanish coasting steamer, called the Machichago, with a cargo which consisted of barrels of spirits, petroleum and above fifty tons of dynamite, was unloading at the mole. Some portion of the inflammable cargo took fire. Efforts were made, under the direction of the town police, acting in the presence of the governor, to remove the dynamite and the pe-

THE RECENT DYNAMITE DISASTER, SANTANDER, SPAIN—ASPECT OF THE MOLE AFTER THE EXPLOSION.

troleum, while a steam tug was brought alongside the burning ship, to tow her away from the quay, which was crowded with people. At half past four in the afternoon, probably from the concussion produced by the sudden bursting of the steam boilers, the whole interior of the vessel was shattered, its contents were mingled together, and the dynamite was ignited; there was a series of tremendous shocks. The ship and the steam tug were blown to pieces, scattered over the harbor and the quay, and at least sixty houses, as well as several vessels lying near, and a train at the railway station, were set on fire by the blazing fragments. The governor of the town and several other official persons of rank were among those killed.

Dynamite, as most of our readers know, is a preparation of nitroglycerine, which latter is made by treating glycerine with a mixture of nitric and sulphuric acids. Nitroglycerine is an oil and possesses the remarkable quality of violent explosion when subjected to slight pressure. It is, therefore, very dangerous to handle. To diminish this danger, and also to present it in the form of a powder, an absorbent substance is mixed with it, which holds the liquid nitroglycerine within its pores and acts as a cushion that prevents the nitroglycerine from exploding under light pressures, such as ordinary handling.

Dynamite is the name given to nitroglycerine when thus protected by an absorbent. Porous microscopic shells, known as infusorial earths, form the best absorbent, and this material is used in the manufacture of dynamite. When dynamite is subjected to sufficient pressure, by concussion, for example, when contained in a bomb which is allowed to fall upon the ground from a suitable height, it explodes with terrific force. The explosive power of dynamite is eight times greater than gunpowder, and in general, for ordinary use for blasting purposes, it is cheaper and safer than gunpowder; but for some kinds of blasting, particularly in coal mining, specially prepared gunpowders are preferred.

The most authentic history of gunpowder attributes its discovery to a German chemist named Berthold Schwarz, some time during the century beginning with the year 1300; and this remained for more than five hundred years the explosive most commonly used until the invention of gun cotton by Schonbein, in 1846, and of nitroglycerine by a French chemist, A. Sobrero, in 1847, in the laboratory of Pelouze, Paris.

The action of nitric acid to render cotton and other substances explosive was discovered by Pelouze in 1838.

THE EVENTS IN BRAZIL.

SINCE the revolution that drove Emperor Dom Pedro from his states, Brazil has been vainly seeking political stability. The state of Rio Grande has for a long time been in open insurrection, and the insurgents are not only holding the central power in check, but have taken a decisive step in seizing Porto Alegre.

The head of the Brazilian government is, as well known, Marshal Floriano Peixoto, who owes his nomination to the supreme magistracy to him who is now his most formidable adversary—Admiral di Mello. Custadio Jose di Mello was born at Bahia in 1841. His career, begun at the naval school of Rio de Janeiro, has been most brilliant. He has often come to Europe charged at various times with important missions. Upon his return to his own country, he played an important part in the councils of state. At the time of the *coup d'etat* in November, 1891, by Deodoro da Fonseca, it was Di Mello who directed the insurrection raised by this excess of power and who re-established legality. At this time he was offered the supreme power, which he refused, and designated to his compatriots as his choice Floriano Peixoto, who was elected and who, as a mark of gratitude, appointed him minister of the marine. However, it seems that the exercise of power led to certain tendencies in Peixoto to use the dictatorial processes of his predecessor. Di Mello was roused by this, and, after several exciting scenes, retired to Rio Grande do Sul, which had already been the hotbed of the preceding revolution. There, on board the armorclad Aquidaban, he rallied around him a true fleet and proceeded against the capital of Brazil. At present his fleet is in the roadstead of Rio, which is justly considered as one of the finest in the entire world. At several points of this roadstead are seen forts that have remained faithful to the government of Marshal Peixoto, with the exception of Fort Armacao, upon the coast of Nictheroy, opposite Rio, which surrendered after bombardment and was occupied by troops landed from the fleet. One fort, that of Villegagnon, has remained neutral. Truly, it is only in America that such a thing could be possible.

However this may be, the present situation of the belligerents is still more singular than that of this neutral fort. In the language of the game of chess, they are both "stale mate." The admiral holds the city under his guns, and is, undoubtedly, able to do it much harm; but he would play at great odds to attempt it, for, although he has entered the roadstead, the forts at the entrance prevent his exit therefrom, the fleet being without communication and unable to obtain supplies.—*L'Illustration.*

THE NEW BRAZILIAN NAVY.

IT has been interesting to note the mushroom growth, during the past few weeks, of Brazil's provisional navy, a navy built in a day designed to combat a navy which it has taken years to bring together.

In the early part of the present revolution in Brazil, it became evident to the government party that the only way to dislodge the revolutionists from their stronghold, the ships, was to get and send other ships to meet them. The position, for some time past, in the game between the two parties might be likened to a stale mate in chess. Admiral Mello, the leader of the revolutionary movement, cannot move, and yet he cannot be mated by Peixoto, the President of Brazil.

In consequence of this state of affairs, Brazil, through her minister at Washington, has been purchasing ships and war material in the United States and France, the greater operations being in the United States. The Brazilians evidently recognize the superiority of American skill, and they thus complimented American shipbuilders and ordnance men.

The ships chosen are of a variety of sizes and shapes and designs, and the armaments are novel.

We have had little or no experience in actual combat with modern war material, and the efficiency and even availability of many weapons of modern design are doubtful.

The Chilian civil war gave us a few lessons from actual experience, especially in the use of auto-mobile torpedoes and the small caliber magazine rifles. The interesting feature about the mushroom fleet is that it is to try the dynamite gun, with which our authorities have been so long experimenting, the Howell torpedo, which is said to be equal, if not superior, to the far-famed Whitehead, and the submarine gun, first designed by Ericsson, but since much improved by others as a result of extensive experiments.

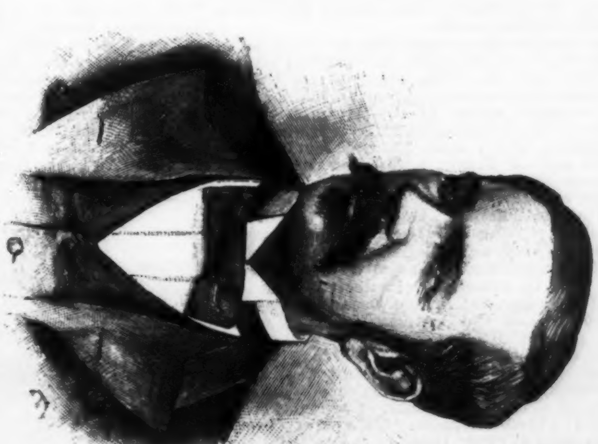
The fleet thus largely depends for its offensive qualities on the aerial torpedo, the auto-mobile, aquatic torpedo and the submarine gun. Each of these carries a large charge of high explosive, and, if a successful hit can be made, one of these charges would disable the heaviest and strongest war vessel now in existence.

The preparing, equipping and arming of this fleet has excited much interest, and especially among naval men. Modern naval warfare is at such a point that it is almost impossible to predict the result of any given conditions. Those who are in the position and possessed of the proper knowledge to give the best judgment on the subject are very doubtful of the success of this heterogeneous squadron operating against the fairly well equipped modern ships of Admiral Mello.

President Peixoto must do something, and, as armorclads cannot be purchased in open market nor can they

ADMIRAL MELLO, COMMANDER OF THE INSURGENT VESSELS.

PLAN OF THE ENTRANCE TO THE HARBOR OF RIO DE JANEIRO.



FLORIANO PEIXOTO, PRESIDENT OF THE UNITED STATES OF BRAZIL.

VIEW IN THE HARBOR OF RIO DE JANEIRO.

be built in a limited time, the present plan is the only the left to him.

What are the chances of this squadron? First, they must get to Rio de Janeiro. There is no question but that El Cid and the Britannia can get there. The Feiseen and the Yarrow boat will go safely on the decks of the larger steamers, but there is grave doubt about the Destroyer, which is too large to be taken on board of one of the steamers and perhaps too small to go by itself. None of the plans of towing it are satisfactory, and no one is confident of its ever getting as far as the West Indies.

Arriving at Rio de Janeiro, what is to become of this fleet as it approaches the rebel squadron? The long range high powered rifles of the rebels will open fire long before any of the offensive weapons of the attacking fleet can be brought to even a possible effective use. The gunnery practice of the Brazilians being notoriously bad, it is quite possible that the Feiseen and the Yarrow torpedo boat, being very fast and presenting small targets, may get near enough to use their automobile torpedoes with effect.

El Cid and Britannia are large targets, and vulnerable to rapid fire guns as well as those of larger caliber, and will find it difficult to get within fighting range. There is no question about the efficiency of their four and seven-tenths inch rapid fire guns, when they arrive within their fighting range, but the dynamite gun cannot be counted on with any degree of confidence at present.

The experiments with the Vesuvius showed how particularly sensitive this gun was to the troubles caused by the unstable platform offered by a ship.

The Destroyer is very slow and cannot be called an efficient boat, and the submarine gun, with which it is armed, though having met with some success lately, is still in the experimental stage.

Though the thorough vulnerability of this fleet must be acknowledged, yet we must not forget that it carries weapons the successful use of which will cause frightful destruction.

It seems to us that President Peixoto must lean heavily for success on the armorclads, Benjamin Constant and Tiradentes, the former of which is an able, well-armed, protected cruiser.

No fleet ever sailed with more chances for and against its success than this provisional squadron, and of the men who go with it, it must be granted that their great pluck deserves good luck.

THE NEW YORK CONTINGENT OF THE BRAZILIAN NAVY.

EL CID, or the Nictheroy, as it has been rechristened, is a new and fast vessel, built to run between New Orleans and New York. She is of 4,500 tons register; length, 380 feet; beam, 48 feet; depth from keel to upper deck, 33 feet; length over all, 406 feet. The Nictheroy is provided with a 43 ton dynamite gun which can throw a 500 pound projectile. She is also armed with several small guns and torpedoes.

The Destroyer is the result of twenty years of Mr. Ericsson's experience in war vessels. She is 130 feet long, 12 feet beam, and has a draught of 10 feet. Her main feature is a 16 inch submarine gun mounted in her bow 8 feet below the water line. The gun fires a projectile weighing 1,525 pounds, being 27 feet 4 inches long, 16 inches in diameter and containing a 300 pound charge of high explosive. A feature of the projectile is a pilot shell, which is detachable, and the object of which is to open a breach of sufficient size through a torpedo net to allow the projectile to pass through.

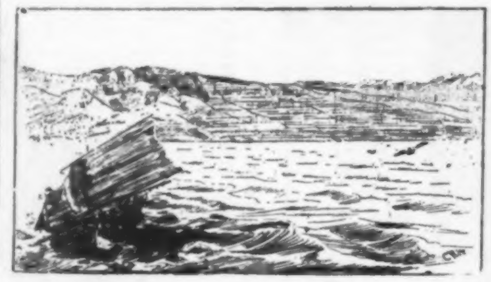
The Britannia, now known as the Brazilian America, was originally owned by the North Atlantic Steamship Company, of Boston, and made trips between Boston and Halifax. The Britannia was built at Bergen, Norway, in 1890. She is of steel, and is 270 feet long, 34 feet 6 inches beam, and the hold is 23 feet deep. She is well armed. These vessels have lately sailed from New York for Brazil, and their careers in the war will be watched with interest.

JAVANESE BOATS.

THERE are probably no waters on the globe which are so little disturbed by the screw propeller of modern commerce, where wind power is wooed with such strange devices, as the torpid expanse of this Mediterranean of the East. Beyond the monthly Queensland mail-boat of the British India line, and the occasional West Australian coaster bound for Singapore, steamer traffic is rare, and is confined to a Dutch colonial or Chinese coaster, trading round from Batavia or Sourabaya to the Borneo and Celebes parts, or perchance a stray Hong Kong-Sydney liner which has borne westward of its regular course.

When the antipodean autumn has set in, it is an enviable experience to run down the tropical eighth parallel of south latitude, cruise along under the lee of the Tenimber and Serawatti groups of islands, then leaving the rougher waters of the Arafusa Sea far astern, make for the towering 10,000 foot landmark of Mount Myrmidon, which rears its majestic head on the northern end of Timor, and looms out even at night time as a guiding beacon to Wetta Passage—the entrance from eastward to the Flores Sea. Once the strong tidal currents of Wetta Pass are stemmed, and the "nasty slop" which rolls up in a cross bad-tempered sea between Timor and Ombar from the Indian Ocean is safely negotiated, no more charming cruising ground can be imagined. Protected from the heavy roll of the misnamed Pacific Ocean by the continents of Borneo and Celebes and the countless islands south and east of these, equally well sheltered from the seas of the Indian Ocean by the long stretch of Java and Flores and their satellites, the fine weather passenger need fear nothing, except upheavals in the way of volcanic eruptions, of which there is daily evidence in these latitudes. Objects of interest now heave in sight at every point of the compass, and the satiated globe trotter—who cares not for the school of whales which is away south on vacation from the warmer waters of the Celebes Sea, and who is long since weary of the myriads of flying fish which have been rising on all sides like larks in a stubble field—climbs out of his deck chair with unwonted energy to watch a volcano on Komba Island, on the starboard hand; or to follow through the clear atmosphere, so long as it remains within binocular range, a queer catamaran crowded with copper-skinned natives, which has been coolly steered close under the port bows, and is now bearing away south for Lomblen or Pantar—two large islands of the Flores group.

The natives of these densely populated islands—bound by no Yacht Racing Association rules, and vex-



A JUNK OFF MOUNT RUIDJAM.

ed with no America Cup deed of gift—design at their own sweet will craft which for grotesqueness and originality place a Bombay catamaran or an Iceland cajak as far in the background as they would distance them in pace; and a double-sail Sumbawa proa, with her huge red striped lateen wings spread to catch a leading wind, has been known to hold her own with the big boats of the British India company, even when these latter are exceeding their ten knot Queensland mail contract gait. As may be expected from the lofty

A TENGAH FISHING BOAT "SNUG FOR THE NIGHT."

nature of the volcanic islands the Flores Sea is of vast depth in many places; still perchance just where the profound chasm of 2,000 fathoms—roughly a mile and a half—has been sounded, a floating structure will be met with at sundown, apparently anchored for the night; a buoyant spider of gigantic growth, with white wide-spreading feelers. This may be a Tengah fishing boat, or a catamaran from Kangeang 150 miles away. The native crew pop up their heads at word from the look-out man, scan you with stolid faces, and

THE JAVANESE FISHING FLEET.

then disappear to await the consummation of the mysterious mixture in the fire-pot which is burning merrily on the lattice footboards. You wonder how they will ever find their way to land, should a gale spring up in the night, until the falling darkness sets in relief a warm beaconlike glow hovering over the mighty crater of Tainborah, which rises precipitously 9,000 feet from the very coast-line of Sumbawa. These frail craft must be far from land indeed to lose sight of this mark in the daytime, or of Mount Ruidjam on

A DOUBLE-SAIL SUMBAWA PROA.

the adjoining island of Lombok. This peak can be seen from a great distance as if suspended in the clouds, and having no earthly connection; but so clear is the atmosphere that when abreast of it it is hard to conceive that it is the highest point in the archipelago, and that its barren cavernous sides and yellow blasted ribs support a head 12,460 feet above your own. Mount Ruidjam is nowadays too dignified to go into eruption, its last performance dating back to the year 1820, when it swamped the island and swept out of existence 14,000 natives.

There are millions of natives left among these islands, however, of whom little note is taken by the western world. Java and Madura alone are estimated to have nearly 22 millions, and when we clear the network of islands round Sapudi Straits and enter the Java Sea, there are ample reasons for crediting the enumeration of the Dutch possessors of the soil without going shoreward. Sweeping out from the low-lying green shore of Java, between Sourabaya and Samarang, may be seen a gigantic fleet of local fishing proas. In the distance it appears as if vast squadrons of white conical casks, bound with hoops of many colors, have floated to a rendezvous, and are now maneuvering for our especial benefit. It is a sight to be reveled in by a colorist—the setting of a background of green cocoa-palms, pisang and coffee plantations, a blue sky and still deeper blue sea in front, and these airy craft flitting hither and thither, propelled by bellying sails of white native calico, striped with bars of all the varying tints of blue, lake, and yellow. After the first big burst of the review they straggle past in dozens, in threes and twos. All have ample crews, and in addition a presiding deity by way of a grotesque wooden idol fixed on the stern of the boat.—*St. James's Budget.*

THE LOSS OF H. M. S. VICTORIA.

THE engravings, for which we are indebted to the *Engineer*, London, are reproductions of photographs appended to Mr. White's report. They show a model of the hull of the Victoria, and serve admirably to illustrate her position just before capsizing; taken with the diagrams, which we produced last week, and the following Admiralty minute, they complete the whole story of the disaster:

ADMIRALTY MINUTE ON THE QUESTION OF CLOSING THE WATER-TIGHT DOORS AND ON THE CONSTRUCTION AND STABILITY OF THE SHIP.

1. The Lords Commissioners of the Admiralty, in their minute, dated 28th October, 1893, on the finding of the court martial which inquired into the loss of her Majesty's ship Victoria, have stated that the question of closing the water-tight doors of the Victoria and the construction and stability of that ship would be dealt with separately; this minute is therefore promulgated. The finding of the court martial concluded with the following words: "The court has placed in the minutes all evidence obtainable with regard to the closing or otherwise of the water-tight doors of her Majesty's ship Victoria, but it does not feel itself called upon, nor does it feel itself competent, to express an opinion as to the causes of the capsizing of the Victoria." Consequently, on receiving the minutes of evidence, their lordships instructed the Director of Naval Construction to make a thorough examination and analysis of those parts of the evidence which throw light on these points. The report which he accordingly prepared—dated the 15th September and published herewith—has been carefully considered by their lordships, with the evidence on which it is based. They find that this evidence is ample, notwithstanding the fact that many officers and men who would have been valuable witnesses were unhappily lost in the disaster.

2. Their lordships have thus been able to complete a full investigation into the causes of the sinking of the Victoria, and to arrive at the definite conclusions hereinafter set forth.

3. The evidence establishes the following facts: (*a*) That after the collision the forepart of the Victoria gradually sunk, and the ship simultaneously heeled to starboard, and that after this had been going on a short time, a lurch occurred which resulted in the capsizing of the ship. (*b*) That up to a very short time—about one minute—before the collision took place, a large number of water-tight doors, hatches and ports were open, and that, owing to the inrush of water, many of these, situated in the forward part of the ship, could not afterward be closed. Many compartments must, therefore, have been flooded in addition to those which were actually breached by the collision. (*c*) That the sea rushing into these compartments gradually depressed the bow of the ship from its normal position—about 10 ft. above water to 13 ft. below water—or a total depression of about 23 ft., while the stern rose about 6 ft. to 7 ft. Thus the forward half of the vessel was almost completely submerged. This extreme change of trim produced a great diminution of her stability. (*d*) During the same time the heel to starboard—the wounded side—very slowly increased, until a transverse inclination of 18° to 20° was attained before the lurch began.

4. This comparatively slow but continuous change of position can only have been caused by the gradual flooding of compartments adjacent to or in communication with the compartments breached by the collision. There are many compartments forward, respecting which the evidence does not clearly show whether or not they were closed before the collision. But if only those which the testimony of witnesses shows to have been certainly flooded are taken into account, the result is a loss of buoyancy sufficient to produce the change of trim and angle of heel observed before the lurch began.

5. The great weight of water thus gradually admitted into the forward part of the ship might eventually have caused the ship to founder by the head. The reason why she capsized before foundering has now to be explained.

6. The armor door on the starboard side at the forward end of the battery, the 6 in. gun ports of that battery, and the turret ports were open at the time of the collision, and were not subsequently closed. Observers on other ships noted that the water had reached such a height as to permit its entry through the open turret ports and armor door; also that the ports at the forward end of the battery on the starboard side were awash at the moment when the lurch commenced.

7. The consequent inrush of water into the battery, accompanied by the descent of large quantities of

water from the upper deck within the battery through open hatchways into the lower portions of the ship, and the inflow of water through the turret ports, necessarily had the effect of suddenly destroying the ship's stability, already very seriously reduced by the submergence of the bow, and of making her capsize.

8. The capsizing of the Victoria, under the special circumstances above described, does not suggest any insufficiency of stability in the design of that vessel. The provision made was ample for all requirements. When fully laden and in sea-going trim the metacentric height was 5 ft., stability reached its maximum at an angle of 34½ deg. to the vertical, and the range of stability was 67½ deg.

9. The question remains, what would probably have happened if all doors, hatches, etc., had been closed in the Victoria before collision took place? Investigation shows that while the loss of buoyancy must in that case have been considerable, yet, making all due allowance for probable damage, the ship would have remained afloat, and under control, and able to make port under her own steam. Her bow would have been depressed about to the water level; her heel to starboard would have been about one-half of that observed before the lurch began; her battery ports would have been several feet above water, and she would have retained ample stability.

10. The detailed evidence establishes the fact that water-tight doors, hatches, etc., in the Victoria were in good order. It contains nothing which suggests a doubt of the efficiency of the system of water-tight subdivision existing in the Victoria. At the parts affected by the collision the subdivision was minute, but doors were left open. According to the established practice of the Admiralty in all classes of ships, the number of water-tight doors is made as small as possible consistently with the essential conditions for working and fighting the ship.

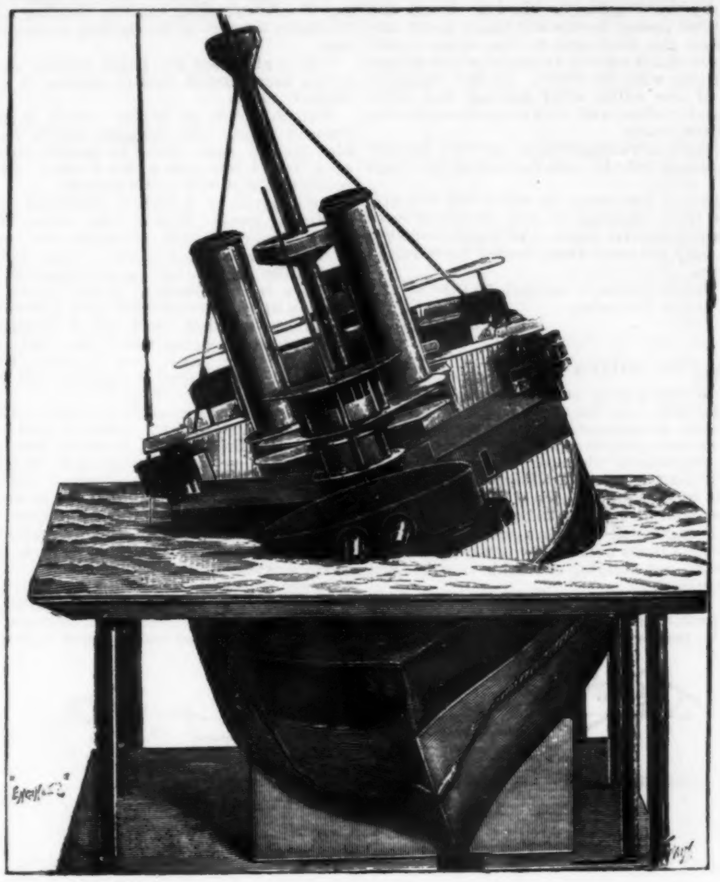
11. The evidence clearly shows that the existence of longitudinal water-tight bulkheads in the Victoria was not the cause of her capsizing. There were only a few minor longitudinal partitions in the fore part of the ship. Many of these were inoperative because of damage or open doors.

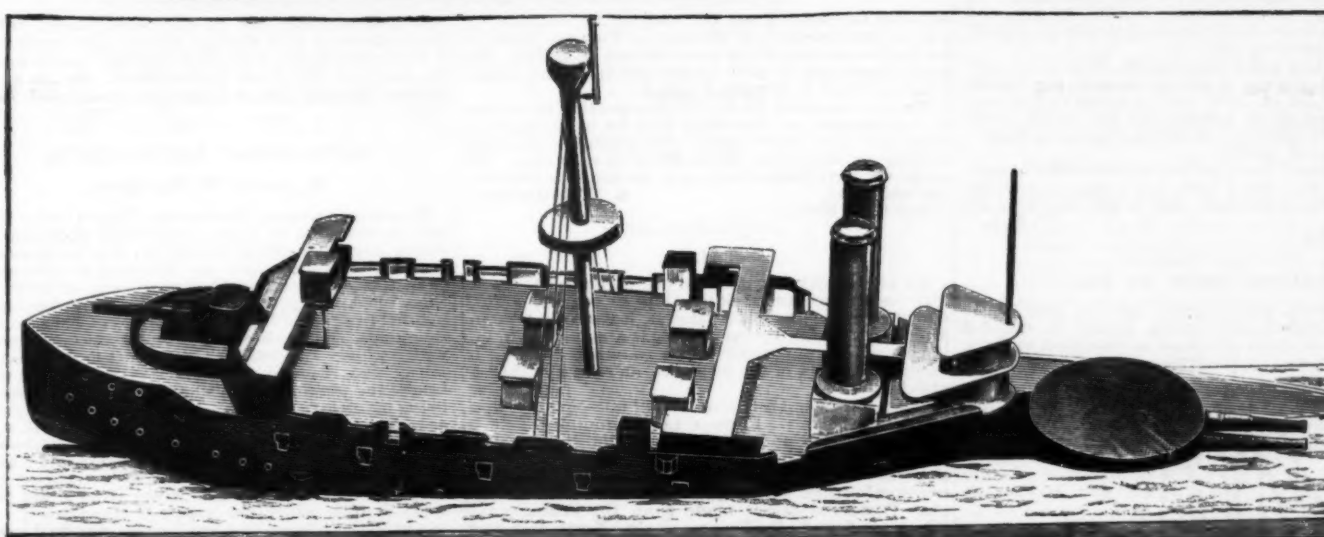
12. It also proves that the loss of the ship was not due to injuries sustained above the protective deck. Those injuries produced a loss of buoyancy forward which was unimportant compared with that resulting from the flooding of compartments below the protective deck.

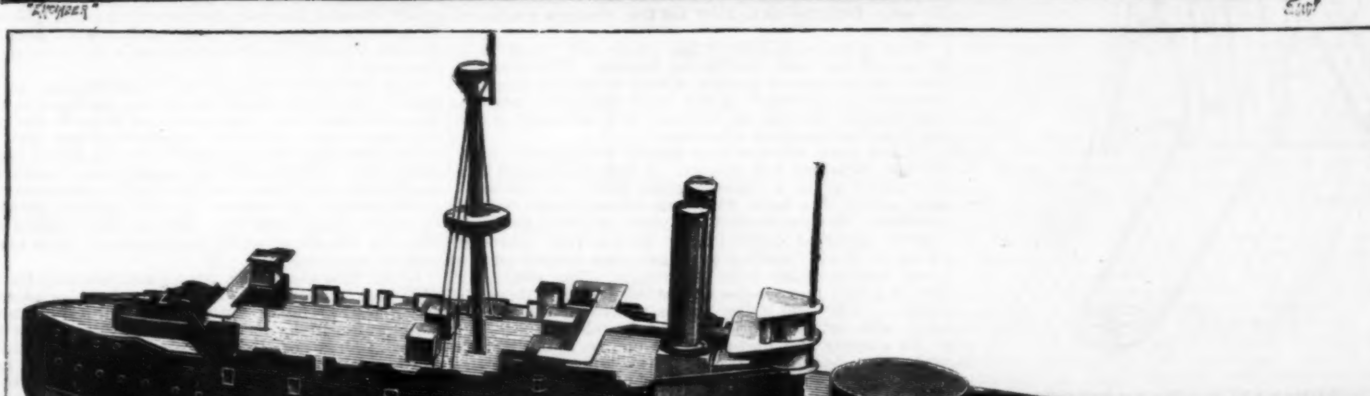
13. The fact that the Victoria was not armor belted to the bow had no influence on the final result of the collision. No armor belt could have prevented the ripping open of the bottom below water by the ram bow of the Camperdown, and the flooding of the compartments to which water could find access through the breach.

14. In conclusion, their lordships are of opinion that the general structural arrangements of the Victoria—similar in many respects to those of other ships in her Majesty's navy—with the arrangements of water-tight doors, armored belt, and protective deck, did not by any fault of principle contribute to the loss of the ship; but that, on the contrary, had the water-tight doors, hatches, and ports been closed, the ship would have been saved, notwithstanding the crushing blow which she received from the Camperdown.

15. The duty remains of taking every possible step to prevent the recurrence, under similar circumstances,







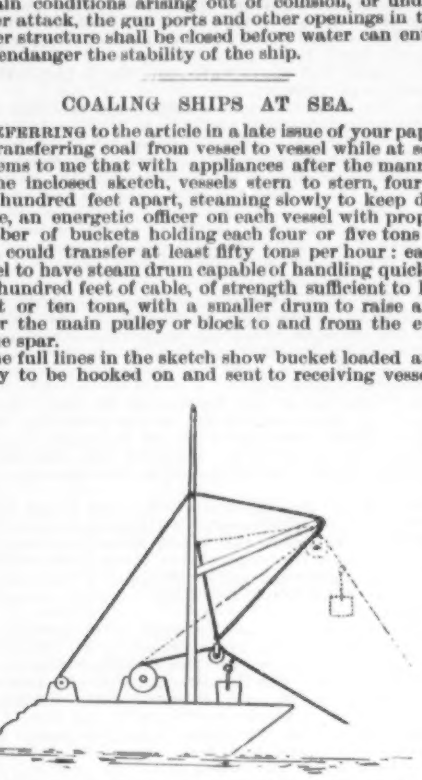
ADMIRALTY MODELS ILLUSTRATING THE LOSS OF H. M. S. VICTORIA.

of the conditions which, after the collision, resulted in the loss of the ship. Regulations will therefore be issued to the fleet which, while maintaining the responsibility and discretionary powers of commanding officers, will insure that, under special circumstances, and particularly when there is risk of collision, doors, hatches, etc., shall be kept closed as far as possible, and men stationed at any that are necessarily left open. These regulations will also direct that, under certain conditions arising out of collision, or underwater attack, the gun ports and other openings in the upper structure shall be closed before water can enter and endanger the stability of the ship.

COALING SHIPS AT SEA.

REFERRING to the article in a late issue of your paper on transferring coal from vessel to vessel while at sea, it seems to me that with appliances after the manner of the inclosed sketch, vessels stern to stern, four or five hundred feet apart, steaming slowly to keep distance, an energetic officer on each vessel with proper number of buckets holding each four or five tons of coal, could transfer at least fifty tons per hour: each vessel to have steam drum capable of handling quickly five hundred feet of cable, of strength sufficient to lift eight or ten tons, with a smaller drum to raise and lower the main pulley or block to and from the end of the spar.

The full lines in the sketch show bucket loaded and ready to be hooked on and sent to receiving vessel; the dotted lines may represent the loaded one coming in on receiving vessel to be dumped and speedily returned, the crew disposing of the load it brought. To facilitate matters, vessels could lie side by side, and have two lines in use, they steaming slowly on slightly diverging lines to keep distance.



By use of this or something similar, there is no need of any special concert of action between the vessels. There can be 500 or 1,000 feet of cable out, or any amount between those figures, and the vessels maintain the original distance; of course, supposing there is sufficient depth of water.

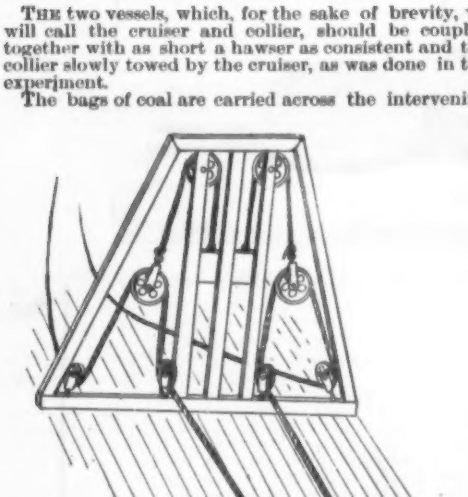
I don't suppose I have got the *ne plus ultra* of coaling vessels at sea; but I think it is a step in advance of the plan you published, even if the coal does get wet. S. A.

Cincinnati, O.

COALING SHIPS AT SEA.

THE two vessels, which, for the sake of brevity, we will call the cruiser and collier, should be coupled together with as short a hawser as consistent and the collier slowly towed by the cruiser, as was done in the experiment.

The bags of coal are carried across the intervening space between the two vessels, suspended beneath an endless cable or wire rope, which is kept in constant motion. The bags are attached to the moving cable by grips or hooks, which are released upon their arrival over the deck of the cruiser, either by hand or by a tripping device. The empty bags are returned on the other lead of the cable.



APPARATUS ON COLLIER.

The cable passes around a large sheave on the cruiser, placed with its axis in a vertical position. Rolls should be placed under the cable near this sheave, and on the collier, to bear the weight of the cable and coal, allowing only the horizontal pull to come on the sheaves. Power for propelling the cable may be applied from either vessel.

The accompanying cut shows the arrangement and apparatus aboard the collier, that on the cruiser not being shown.

As the cable leaves the drive sheave at the left-hand side it runs under an idler at the base of a frame constructed of heavy timbers and firmly held in place on the deck. From this idler it passes over a tension pulley or tightener, suspended in such a manner as to be drawn upward by the weights, as shown. From the tightener the cable passes downward again under another idler, across the deck and to the other vessel. The tightener is inclined and on an angle which brings the two sides in line with the idlers. In like manner, the other side of the cable, after leaving the drive sheave, passes under idlers and over a tightener on the opposite side of the frame.

It might be found advantageous to use two smaller sheaves on the cruiser side by side instead of one large one.

The employment of two loops, as indicated, will prevent the cable from slipping on the cruiser sheave when run out or in; shorter loops, and consequently a shorter frame, may be used than would be required with a single loop.

The weights should be heavy enough to take all unnecessary slack out of the cable.

Syracuse, N. Y. S. H. RIKER.

COALING SHIPS AT SEA.

WE propose to coal a ship at sea by the following plan. The collier is to tow the cruiser at a rate of say four miles per hour, an endless cable of wire works between them as shown, propelled by the power of leading vessel; an adjustable elevator which will raise sacks to a convenient height to attach to the cable while in motion by a simple device is provided. The coal can then proceed on its way to cruiser.

Said sacks or cages will have an arrangement to dump their contents upon arriving at the proper place on the cruiser, thus not obliging the cable to stop until the cruiser is supplied.

The speed of loading can be regulated by the speed of the cable, which, at a rate of about four miles per hour, same as the progress of the vessels, would give a capacity for carrying say two tons per minute, and, by a little extra exertion on the part of the sack fillers in leading vessel, double the quantity can be loaded. We have it arranged so as to experience no serious inconvenience while in disturbed waters.

A, tow line; B, carrying cable; C, loaded sacks; O, empty sacks; D, shield.

We also commend its use for transporting provisions or merchandise, as the sacks may be made large or small and also water tight. Our intention is at this writing to carry from 100 to 200 lb. in each sack. All parts we have studied out so as to satisfy a practical eye and mind. A. D. ADAMSON.

Bay City, Mich.

TALC.

AN article which is much in use everywhere, is talc. Talc bears the same relationship to soapstone that marble does to limestone: that is, it is a very superior kind of soapstone, just as marble is a superior kind of limestone, the superiority being so marked that it is, except in the eye of the geologist, an entirely different article.

There are several different sorts of talc—gray, yellow, white and fibrous. Fibrous talc is found chiefly in New York State, and is used chiefly in the manufacture of paper. All talc is absolutely fire proof, and is therefore extremely valuable for the manufacture of non-combustible wall papers, paper window curtains, etc. Powdered talc is made from the ordinary talc which is found in France, Italy, North Carolina, Georgia, and Alabama. This sort of talc is used largely by soap factories as a filler for the cheaper grades of soap.

Even in its crude state it has a very oily "feel," and is one of the best lubricants known. When mixed with the commoner grades of soap it renders them as pleasant to the touch as the most expensive brands, and renders the skin smooth and soft, although it has no cleansing qualities whatever.

Of late years talc has been largely used in the manufacture of patent wall plaster. A little talc mixed into the plaster gives a smooth, glossy finish to the walls and ceiling of a room which no other substance will produce. Several years ago a party of Cincinnati capitalists invested quite largely in the talc mines of Western North Carolina and have since reaped quite a neat sum annually from the output. The mining of talc is a very inexpensive operation, as it is in its crude state so soft that it can be easily loosened from the vein with ordinary pickaxes and shovels.

Its scarcity and usefulness, of course, make it very valuable; hence the profit to the mine operators is great. More than one carload of crude talc has been sold in Cincinnati for $600.

The best talc found in America, and perhaps in the world, is found in mines near Kinsey, Cherokee County, N. C. These mines are owned by Cincinnati capitalists and a large portion of their annual output is consumed by Cincinnati manufacturers.

One common use to which talc is put is the manufacture of infant powders. Talc powder is so exquisitely soft and fine grained that it softens the skin of the reddest, tenderest baby, and, by reason of lubricating properties, it prevents chafing or irritation of any sort, absorbing all greasy fluids which gather in the folds of flesh which predominate in chubby darlings, thus preventing prickly heat and other baby skin troubles.

Talc is largely used in Cincinnati foundries for foundry facings, being fire proof. Talc powder is invaluable for this purpose. For the benefit of some it may be well to state that by "foundry facing" is meant the substance used to mould metal in. For example, when a casting is to be made, an impression is first made in a box of fine sand with a mould "form." This indentation is then filled with talc powder, which is again indented with the mould. The result is that the last indenture has a lining of fire proof talc, which prevents the molten metal from burning the surrounding sand or turning it to glass, and at the same time gives the casting a smooth, polished surface.

Talc is also used by India rubber manufacturers to soften their output and to render it pliable and less liable to crack.

French chalk or tailors' chalk is quite a familiar form in which talc appears before the public. It is also used in shoe stores to enable vain people to slip on a No. 10 foot into a No. 2 shoe. Stove fitters also make use of it with great success.

An analysis of a perfect specimen of talc gives the following result: Water, 4·65; silica, 62·50; magnesia, 31·20; iron oxide, 0·82; alumina, 0·51; calcium, a trace; and of manganese, a trace. Total, 99·68. One use to which the article can be conveniently put by housekeepers is in removing grease spots from clothing. Take a little pure powder and sprinkle it upon the toughest, stickiest sort of a grease spot, put a piece of blotting paper over this and a hot iron on top of the blotting paper, and the most unsightly grease spot that ever spotted a summer suit will come out as if it wanted to.

Previous to the discovery of fire brick, talc was very generally used to line furnaces and chimney places with. The fire brick is so much less expensive than talc that since its discovery talc has been very little used for these purposes, although the fact that talc is absolutely fireproof renders it the most superior article which can be used for these purposes.

In its native mountains talc lies buried in veins which vary in extent from an inch wide to the width of an early morning sidewalk.

It lies in leaves or scales, very much like slate, but is very easily sawed or chipped. Although the leaves will not bend, they break and crumble very easily.

During past years hundreds of carloads of talc have been used in Cincinnati by all lines of trades, but few people know of this strange article in its crude form. It is so exceedingly soft that it is not gritty even to the sensitive test of the human teeth, and as a complexion powder has no equal.—*Cincinnati Times-Star.*

MECHANICAL EQUIVALENTS.

By Prof. C. W. MACCORD.

THE accompanying illustrations, Figs. 1 to 5, exhibit the construction of three mechanical combinations, which may be described as follows: Fig. 1 represents a disk in the face of which are two slots at right angles to each other, with a block sliding freely on each slot; these blocks are pivoted to a bar B, whose free end is pivoted to another block which slides in fixed horizontal guides. Fig. 2 shows an annular wheel *w*, gearing with a pinion P of half the size, which is hung on the pin of the crank C. The bar B is rigidly fixed to the side of the pinion by means of two screws, its free end being pivoted to a block moving in horizontal guides, as in Fig. 1. The journal of the wheel W is hollow, and the shaft S of the crank C turns within it, as shown in the sectional top view, Fig. 3. Figs. 4 and 5 are respectively a front and a side view of a train of three wheels in outside gear. The wheel W′ is keyed to the shaft S, upon which the crank C turns freely. The wheel P′ turns upon the crank-pin *p*, and to its side is rigidly secured a bar B, the free end of which moves in a horizontal line as in the preceding cases. The wheel W′ is twice as large as P′, and both wheels gear with the idle wheel I, which turns upon a pin also fixed in the crank C.

Now were these three pieces of mechanism actually made of the dimensions here shown, we think it will be admitted that they would not look alike to the casual observer; and were these representations free from other lines than those alluded to in the above descriptions, their dissimilarity in appearance would be so great that even those familiar with mechanical movements might be forgiven for not at once perceiving their substantial identity. But we have added a few lines, by the aid of which we think that such identity may be made clear.

In the first place, Fig. 2 is an arrangement like that of Watt's familiar sun and planet wheels, applied to a direct-acting engine, with the exception that the sun wheel is internally instead of externally tangent to its planet. Drawing the pitch circles, the circumference of the smaller passes through the center of the larger, and the point of contact *a* is found by producing the center line of the crank C. The center line of the bar B cuts the pitch circle of P at the extremities of a diameter, and two diameters of W through these points of intersection will be perpendicular to each other.

In Fig. 2 the teeth are of the ordinary epicycloidal form, one wheel having twenty-four teeth and the other forty-eight; but so long as this ratio of one to two between the diameters is preserved, the teeth may be of any forms that will work together correctly.

In the well known epicycloidal modification called pin gearing, the pitch circle of the pin wheel is the describing circle for the teeth of its mate; if the former be the pinion in this case, the hypocycloid traced by rolling it within the other will be a radial line, and two parallels to this radius, tangent to the assumed circle of the pin, will be the outlines of the teeth of the larger wheel. And a wheel will work, in inside gear, with a pinion of only two pins, the four teeth of the

annular wheel then forming merely two diametrical slots perpendicular to each other.

But this is precisely what is represented in Fig. 1, with the exception that the slots are wide enough to admit the sliding blocks by which the pins are surrounded, which obviously does not in any way modify the action.

Describe a circle through the center of the pins about o, the point midway between them; since the center lines of the slots are perpendicular to each other, the circumference of this circle will pass through their intersection, O: draw O o and produce it to cut the circumference at a, and about O describe a circle with radius O a. It will then be apparent that this combination, like that of Fig. 2, consists of a sun and planet wheel, and that its operation can be explained in no other way. The peculiar forms and proportions of the teeth enable us to dispense with the crank, which, however, as indicated by the heavy line Oo, might be retained if in any case it were desirable. But whether it be or not, it is now seen that Figs. 1 and 2 are in fact absolutely identical, both practically and theoretically.

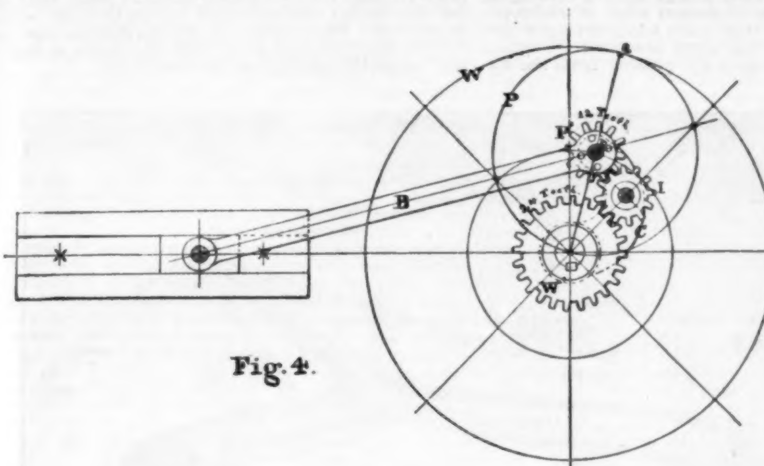


Fig. 4.

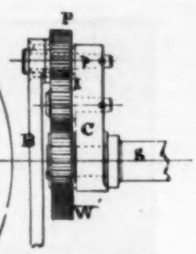


Fig. 5.

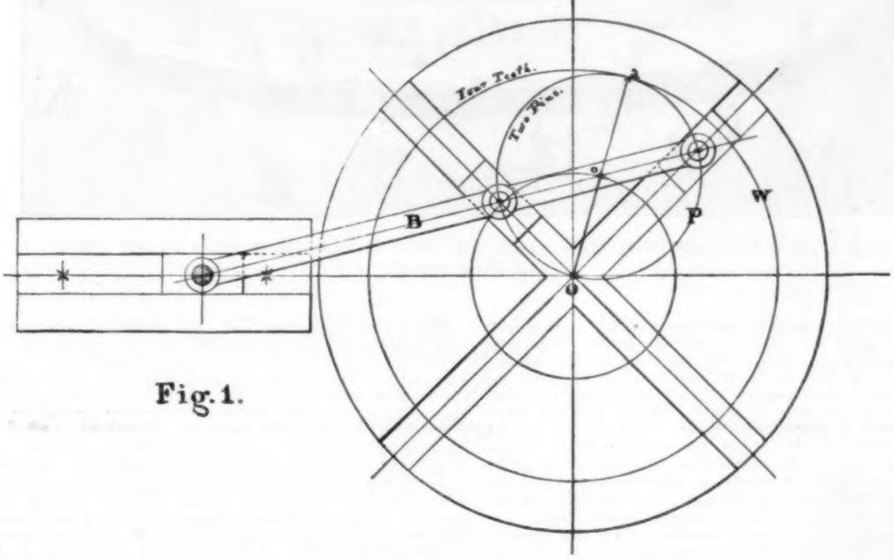


Fig. 1.

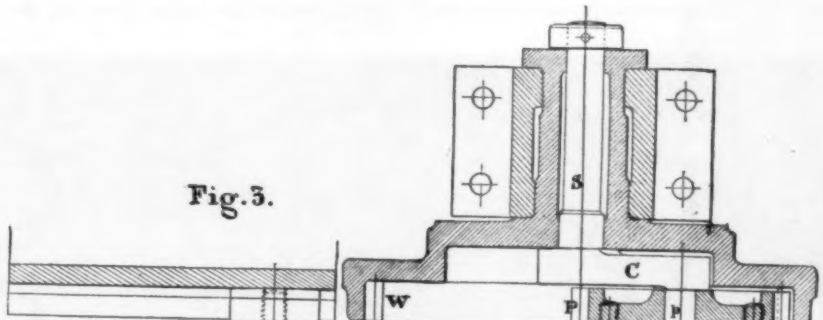


Fig. 3.

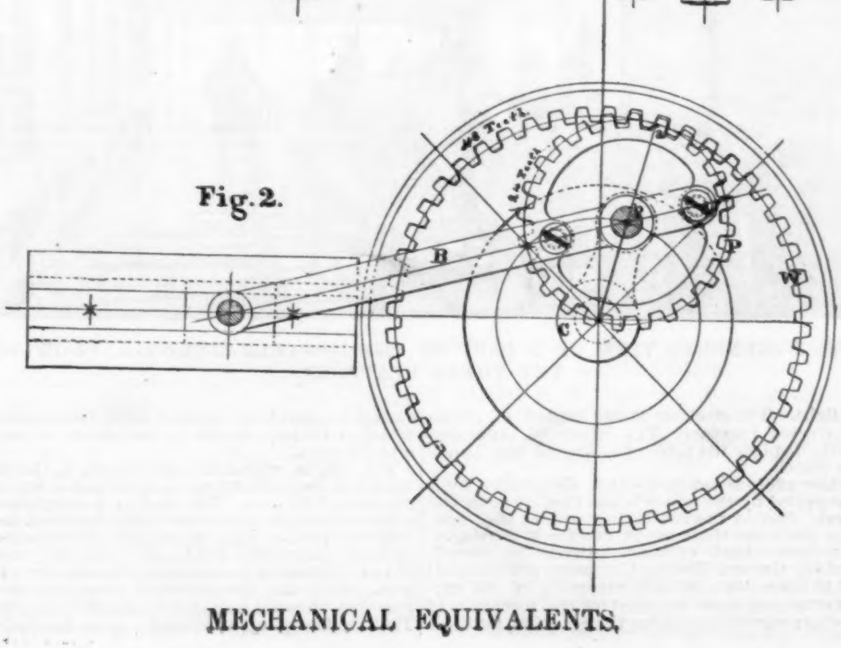


Fig. 2.

MECHANICAL EQUIVALENTS.

And the three-wheel train of Fig. 4 produces the same result as the two-wheel train of Fig. 2. If in each device we disconnect the bar B, hold the crank still, and turn the larger wheel once, we see that P′ in the former and P in the latter will turn twice in the same direction. That is to say, both the directional relation and the velocity ratio are the same in the two trains; which are therefore equivalent. Now in Fig. 4 describe about the center of P′ a circle, P, through the center of W′ and another one, W, tangent to it, about the center of W′. Then it will be apparent that the motion of the bar B in this third combination is precisely the same as though it were carried by a wheel of which P is the pitch circle, gearing with the annular one having W for its pitch circle. And the center line of B cuts the circumference P in two points, which obviously correspond to the centers of the two pins in Fig. 1: two lines drawn through those points and the center of W′, intersecting on the circumference of P, will be perpendicular to each other.

The pitch circles are drawn of the same diameters, and the bar B has the same angular position, in all three combinations; which will enable the reader more readily to trace the relations existing between them as above set forth.

Now, the relation between the first two is different from that between either of them and the third. The former is one of actual identity, like that between an eccentric and a crank; although the two-wheel planetary structure in Fig. 1 is so effectually disguised by the unusual forms of the teeth and the suppression of the train arm, that without the introduction of the pitch circles it might easily escape detection. But the third combination cannot properly be called identical, in the same sense, with either of the others, although it produces the same results. Its relation to them is, we think, a good illustration of what is called "mechanical equivalence."

This phrase, "mechanically equivalent," is quite frequently met with; but we do not remember having ever seen a clear and positive definition of it, or any statement of tests or rules by which to determine whether any two devices under consideration should or should not be so designated. Without presuming to supply this deficiency, we venture to illustrate our conception of the meaning and applicability of the term by a few examples.

It was just remarked that the third device above described produces the same results as the others. But that circumstance alone is not, in our view, sufficient; the result must be produced in substantially the same way. This point may perhaps be made clearer by another illustration. It would hardly do to say that all elliptographs are alike because they all do the same thing. The ellipse may be defined in various ways, and drawn by means of instruments, some of which are based upon one definition and some upon another. Thus, that curve is a section of a *cone* by a plane, and an apparatus for drawing it has been made, in which this property is embodied. Another one is based on the definition of the curve as a section of a *cylinder* by a plane.

We should regard these as mechanically equivalent, the one being merely such a modification of the other as is due to the selection of the limiting case in which the vertex of the cone is infinitely remote. The ellipse is also a special case of the epitrochoid; a fact embodied in several instruments, all of which are in this light equivalent, since the relations between the base circle and the rolling circle are and must be alike in all; although the details are different and the appearances dissimilar. But no contrivance of either class is in any respect equivalent to any one of the other class, while all of them are radically different from another, whose fundamental principle is that every point of the ellipse is equally distant from a given point and from the circumference of a given circle.

Again, in White's parallel motion, the end of the piston rod is constrained to move in a hypocycloidal path, which in this special case is a right line; in that of Watt, its path is a portion of a lemniscate in the immediate vicinity of the point of contrary flexure, where the curvature is practically inappreciable; in that of Stevens, it is controlled by the reaction of two connecting rods, jointed to the crosshead and to two cranks rotating in opposite directions; and in that of Peaucellier, by a combination of links and levers, of which it here suffices to say that it differs from either of the others as much as they differ among themselves. The practical result is the same in all, but, while some forms of those of Watt and Peaucellier may somewhat resemble each other in appearance, there is no possible way in which any two of these combinations can be shown to involve the same mathematical considerations, or in any respect to be mechanically equivalent.

In short, the very nature and action of all mechanism depend upon determinate motions, and the same motion for the same purpose may often be produced, as in the above instances, by many different combinations. But the component parts of these have definite forms and dimensions, and the operation of every one of them is capable of reduction to geometric principles and properties. And it is by a comparison of these fundamental principles according to the view here suggested, that the questions of identity, equivalence, or difference, of any given devices are to be settled, and not by superficial likeness or unlikeness in details.

Those shown in the figures were selected, not by reason of their adaptation to any purpose, but because they are good illustrations of the fact that arrangements which in appearance bear little resemblance to each other, and may be correctly described in such a way as not to suggest their close relationship, may yet prove upon application of this test to be substantially the same.

IT is said that two French scientists have lately discovered an entirely new property of Faraday's disk, and that the result may be an important improvement in the dynamo.

THE MOVABLE SIDEWALK AT THE CHICAGO EXPOSITION.

THE idea of utilizing, as a means of transportation or locomotion, a pathway, a surface or even vehicles moving in a continuous manner with a uniform speed is not new in itself. The continuous elevators installed in some of the large houses of London, the inclined elevators of the Saint Lazare station, the endless carriers employed in the great grain elevators of Chicago, are merely varied applications of the same principle, but the movable sidewalk of the World's Fair constitutes the first demonstration of the

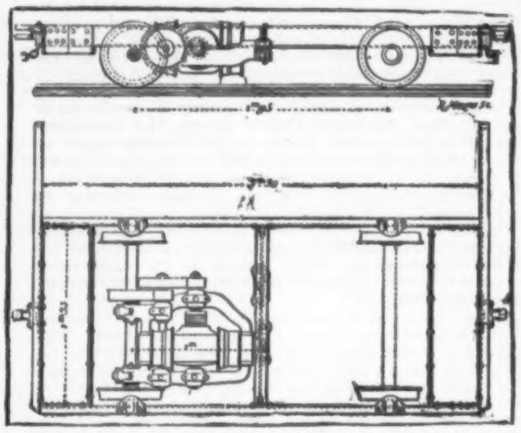


FIG. 1.—ELEVATION AND PLAN OF THE TEN MOTIVE TRUCKS OF THE MOVABLE SIDEWALK.

practical use of such a system for the simultaneous and continuous carriage of a large number of passengers. The idea of a continuous platform moved electrically is, however, absolutely French. It is due to Mr. E. Henard, who, as long ago as 1887, proposed the application of it to the Exposition of 1889. His project has been described in these pages.

The advantages claimed in favor of this special system of locomotion are numerous. The principal of these, briefly stated, are as follows: Relative lightness of the structure and rolling stock, the load being uniformly distributed over a great length; flexibility of the line, which adapts itself to all curves, ascents and descents; facility of heating, in consequence of the continuity of the system; continuity of motion,

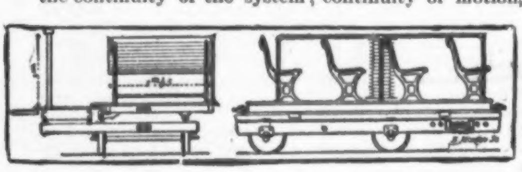


FIG. 2.—LATERAL AND LONGITUDINAL VIEW OF THE TWO MOVABLE PLATFORMS.

which permits of going from one point to another without great absolute speed, on account of the suppression of stoppages and waiting at the start; finally, great carrying capacity, which, at the speed adopted at Chicago, exceeds 40,000 persons per hour, supposing all the seats occupied, while cable cars are capable of carrying but 12,000 persons per hour.

Fig. 4 gives a general view of the movable sidewalk, which has the form of two parallel lines, outgoing and incoming, connected by loops at the extremities. The total length of this platform is 4,500 feet. The platform is double. The wider part, mounted upon a series of wheels and motive trucks, moves forward at a normal speed of about three miles per hour. Upon the upper part of the fellies of the wheels that support this first platform rest two long endless bands of steel that support the second and narrower

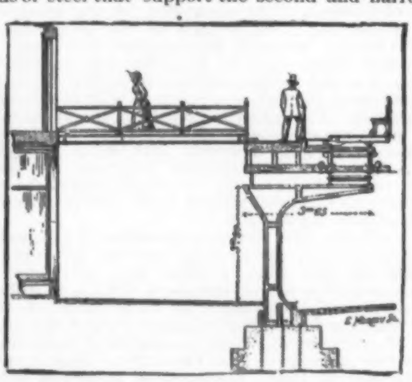


FIG. 3.—PROJECT OF A MOVABLE SIDEWALK FOR STATE STREET, CHICAGO.

platform upon which the seats are arranged. As well known, in a wheel rolling upon a plane, the speed of the point of contact is *null* at every instant, that of the axis is *equal* to the speed of displacement, and that of the upper part diametrically opposite to the point of contact is *double* the speed of displacement. The second platform, which rests upon the wheels, moves forward, therefore, with a speed double that of the first, say at the rate of six miles an hour. The object of these platforms of two velocities is, as may be guessed, to permit of the easy access to the rapider platform in passing through the intermediate one, Fig. 2. The passage from one platform to the other presents much less difficulty than the getting on or off a street car running at a feeble speed.

Figs. 4 and 5 show the principal arrangements adopted for solving the problem. The first platform rolls over a track of $8\frac{3}{4}$ feet gauge, forming a closed circuit of 4,300 feet in length.

Over this track rolls a continuous platform of the same length, supported by 350 trucks, with wheels 18 inches in diameter. These trucks carry a flooring 32 inches in width, upon the external edge of which are fixed, here and there, iron posts 3 feet in height and $1\frac{1}{8}$ inches in diameter, that serve as a point of support to inexperienced passengers for passing from the sta-

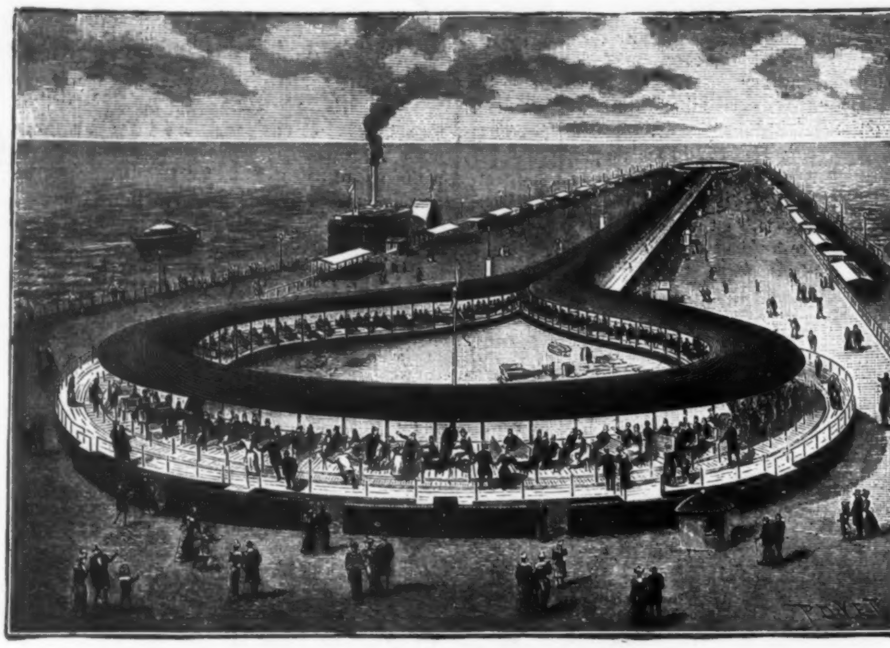


FIG. 4.—GENERAL BIRD'S EYE VIEW OF THE MOVABLE RAILWAY AT THE CHICAGO FAIR.

tionary to the movable platform, which moves at a uniform speed of three miles an hour. Two long steel bands fixed under the flooring of the second platform, roll over the 1,400 wheels that support the first and give the former a double speed, say six miles an hour. It likewise is formed of 350 distinct parts of the same length as the trucks and jointed in such a way as to be able to easily pass over curves. Covering bands overlap the platforms and covering joints connect the different trucks, in order to assure the continuity of the platform, despite the obliquity of the axes of the trucks in their passages over curves.

As the principal weight constituted by the movable platform, its seats and the passengers, bears directly upon the wheels through the intermedium of the bands of steel, the axles and the journals of the wheels

FIG. 5.—GENERAL VIEW OF A PART OF THE MOVABLE SIDEWALK, SHOWING THE THREE PLATFORMS.

are very light. The steel bands are formed of pieces strongly riveted together. The effects of expansion but slightly displace the table of rolling of the bands upon the wheels.

The entire affair is set in motion electrically by a current supplied by the power house that actuates the intramural. Out of the 350 distinct trucks that constitute the platform, there are 10, one for 35 carriages, that are motors. Each of them carries two electric motors, of the General Electric Company, of a nominal power of 12 kilowatts. At each extremity of the carriage are arranged boxes designed for the reception of ballast, with a view to increasing the adhesion, for these trucks, upon the whole, are very light, and each must haul 34 simple ones, since there is but one motor for 35 trucks.

The current enters through a copper wire mounted upon special insulators and arranged at the level of the rails. The trolley rolls at the upper part of the wire, instead of touching the lower part, as in ordinary electric tramways. The return of the current takes place through the continuous bands of steel fixed under the second platform and rolling over the wheels of the first. The position of the conducting wire under the platform does away with all danger, as well as the unsightly aspect of an external wire.

The entire equipment of this mode of locomotion was established by the General Electric Company.

The internal side of the high-speed platform is protected by a hand railing of iron tubes one inch in diameter and a wire netting. Each of the 350 parts of the movable platform carries four seats, capable of accommodating four persons each. In order to pass from the low speed to the high speed platform, one can take as a point of support the external angle of each seat, but, with a little practice, it becomes very easy to pass from one platform to the other without taking any point of support, for the relative speeds are very feeble and the platforms are very sensibly at the same level.

The total weight of the movable platforms is 450 tons. As there are four seats per truck, each accommodating four persons, and as there are 350 trucks, the system is capable of carrying 5,600 passengers seated, which at 150 pounds per person, mean weight, represent 392 tons.

The weight, with a maximum load, is, therefore, 860 tons, but the ordinary mean total load is less, and does not exceed 600 tons. The electric power expended to actuate this system is remarkably constant, seeing the uniform speed and the great mass set in motion. It is, moreover, relatively feeble, and does not exceed from 80 to 90 kilowatts, according to the number of passengers. Such are the principal arrangements of the movable sidewalk installed by the Multiple Speed and Traction Company, of Chicago, upon the Casino wharf

at the World's Fair, and at right angles with the shore of Lake Michigan.

It was designed originally for the easy and rapid carriage up to the entrance of the Exposition, properly so called, of the numerous travelers who should arrive by Lake Michigan and land upon the wharf. Experience showed that there was little foundation for such anticipations, for it required but a small number of landings to receive the passengers, even on the busiest days. The utilization was, therefore, transformed. The means of effective carriage became for the visitors a means of agreeable and refreshing locomotion, which was highly appreciated during the summer, when the heat rendered the galleries almost unsupportable. There was nothing more delicious, and we have experienced it, than to pass an hour in being carried without jolts and almost without noise by this original means of locomotion, seeing the panorama of the White City unroll before one's eyes, sheltered from the rays of the sun by an awning and refreshed by the breeze from the lake or that produced by motion forward.

Our description would not be complete if we confined ourselves to the purely experimental movable sidewalk that we have just presented to our readers. The aims of the Multiple Speed and Traction Company, of Chicago, are more ambitious. It proposes, in order to remain faithful to its title, to employ systems with three, four and even five platforms, the latter to attain speeds of 6, 9, 12, and 15 miles an hour, with seats provided in each case for one, two, three or four passengers. The power of vehiculation would then reach unexpected proportions. Thus, with four open carriage platforms, and seats for four persons, there would pass no less than 84,480 places per hour at a given point. Such provisions exceed what will be needed for a long time to come. In more limited proportions, in confining one's self to a two-platform system with a single longitudinal seat, the number of seating places offered would exceed 10,000 per hour. A similar project has been studied for State Street, one of the most frequented thoroughfares of Chicago (Fig. 3). In this project the ascending and descending track are arranged parallel at the edge of each sidewalk, one on one side and the other on the opposite side of the street. Each rests upon a system of pillars, of which the aspect appears quite unsightly, but which lend themselves happily to modifications from a decorative point of view. The stationary platform, which the passengers reach by means of stairways properly distributed at the street crossings, is about 5¼ feet in width, the low speed platform 32 inches and the high speed 5¼ feet. As the lateral seat, which extends all along the movable sidewalk, occupies scarcely more than 24 inches, there remains in front of the persons seated a space 32 inches in width, quite sufficient to allow the passengers to reach the parts of the seat where it is unoccupied, if, in consequence of a false maneuver, they have entered the full-speed platform opposite places already occupied.

Transverse bridges are likewise provided to allow of access from the second story of houses.

At a speed of six miles an hour, and supposing a width of 24 inches per place, there would pass at any one point 16,000 sitting places per hour, and, in case of urgency, a larger number of places disposable, provided that the bolder travelers consented to remain standing.

However this may be, the movable sidewalk of the World's Fair has been a technical success, and also a success as regards curiosity. It is our conviction that such a mode of locomotion, established as an aerial line upon the wharves of the Seine, the down track on one side and the up track on the other, would constitute one of the surest attractions and one of the most effective innovations of our Exposition of 1900, in awaiting an elevated railway that we are ever hearing spoken of, but which we never see realized.—*La Nature.*

IMPROVED DUMPING CAR.

AMONG the Columbian Exposition exhibits was the Thacher compressed air dumping car which we illustrate, patented in 1889, and used in Colorado in the mines. It handled the material so cheaply that in 1892 a company was formed to build the cars for handling gravel, broken stone, ores, coal, etc., and, for the short time that the company has been formed, they have met with success. Our engravings and the following particulars are from *Engineering*. The first cars built were small and used on narrow-gauge roads, but all the late cars are standard gauge and hold 9 cubic yards, or 40,000 lb. The working parts are simple and cheap, and easily kept in repair. In the building of the cars, the makers have adopted the standards of the Railway Master Car Builders' Association.

It will be seen that the car body is pivoted on its center line, so that a small effort will tip it. Two 1¼ in. air pipes running the entire length of the train enable the energy from a reservoir of compressed air on the engine to be applied on each car for dumping it, and returning it to the normal position. When the body is in the horizontal position, carrying its load, it is locked there by a latch bar, the catch being held on by a weighted lever. This catch is pulled off, when tipping is to be effected, by the driver admitting air to one train pipe, and through the connection to the latch cylinder. This connection delivers through a port close to the front cover of the cylinder, forcing back the piston and raising the latch. As the piston moves it uncovers the port leading to the pipe, which communicates with the bottom of the lifting cylinder. The piston of this cylinder is thus forced up by compressed air passing through the latch cylinder, and the car is dumped. In this position it can be retained as long as desired. When it is to be returned to the normal position, the air is allowed to escape from the train pipe, whereupon the counterweight pulls back the piston of the valve cylinder. The pipe is thus connected to the atmosphere through the hole in the latch cylinder. If air be now admitted to the other train pipe, it enters the opposite end of the latch cylinder, completes the stroke of the piston, if this has not already got to the end of its stroke, and finds access through the pipe to the upper side of the lifting piston. The car body then comes back to its usual position, and the supply of compressed air is cut off by the driver. The car body automatically latches itself when it gets into the correct position; buffer stops are provided to stop its descent without shock.

When the car has to tip on both sides an oscillated cylinder is used, the normal position of the piston being in the center, so that it can travel either way, according as the tipping is to be to right or left. There are two semicircular latch bars, the two latches being operated together by a single latch cylinder. A three-way driver's valve is used, by which air is directed into either air pipe, and also evacuated to the atmosphere.

One great advantage of these cars is that they can be dumped while the train is in motion, thereby saving time. They will also handle more material with less cars, keeping the men busy all the time. The cars are working satisfactorily in several places in the United States and Canada, and are giving the very best of satisfaction. The trucks of these cars are of special design, and are strong, so as to stand the hard work of construction. They are not easy to derail in case the track is in bad shape, which is often the case on new work. The makers—the Thacher Car and Construction Company, 917 Havemeyer building, New York—are now prepared to build eight-wheeled cars having a capacity of from 60,000 lb. to 80,000 lb., and which will dump on both sides of the track, so that the cars can be used in general railroad traffic.

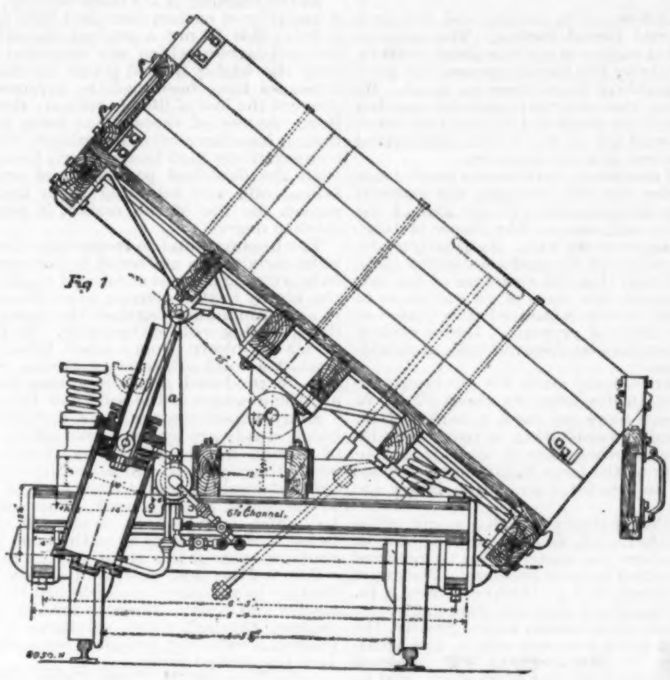


FIG. 2.

IMPROVED DUMPING CAR.

CARBON AND ITS USES IN ELECTRICAL ENGINEERING.*

By CLARENCE M. BARBER, C.E., Member of the Civil Engineers' Club of Cleveland.

PREPARED FOR THE INTERNATIONAL ENGINEERING CONGRESS OF THE COLUMBIAN EXPOSITION, 1893.

IN the year 1810, Sir Humphry Davy connected the poles of a battery of 2,000 elements by two charcoal points, and produced one of the most brilliant artificial lights that had doubtless ever been seen.

So little value was attached to this experiment that it was merely entered in the note book of the great physicist, and remained there apparently unnoticed until twelve years later, when it appeared as a communication to the Royal Society. Scarcely do we find a more striking example of the great advancement in electrical science than when we note that this bright spark has grown in strength and beauty, until now there are required to feed its ever-spreading rays 200,000,000 of carbon pencils for the present year in the United States alone.

In electrical engineering, the term carbon is used to designate an artificial solid, which through mechanical or chemical means is derived from some of the natural forms of carbon. It is moulded under great pressure into cylindrical pencils for arc lighting or into rectangular blocks or plates for battery or other uses. It is not the purpose of this paper to describe minutely the process of making carbon, nor is it necessary, as there are published descriptions which cover the ground fairly well. However, an outline of the general principles may not be out of place.

The materials usually employed are coke and pitch. The coke should be as free from solid impurities as is obtainable. Petroleum coke is largely used, although other varieties are often sufficiently pure for the purpose. It is ground to powder, and the volatile components are driven off by heating in retorts. Melted coal tar pitch is then thoroughly mixed with it, and for some kinds of carbon lampblack is also added. The mixture is then cooled, again ground to powder, and is then ready to be moulded or forced.

The process of moulding consists of filling the material into steel moulds, which are made in two equal parts, so arranged that the lower half of the mould will contain a sufficient quantity of the material for the entire charge. The upper half is then placed in position upon its counterpart, the mould is placed in a furnace and heated sufficiently to soften the fusible ingredients. It is then put under a pressure of about 400 tons, after which the sixteen pencils, or carbons as they are called, are removed from the mould. After cooling they are ready for the next process, which consists in handling the carbons one by one, examining and trimming off the webs which usually occur between the individual pencils as they lie in the mould; they are then packed in furnaces holding from 30,000 to 50,000, where they are baked at a high temperature for about 100 hours. After cooling for a like period

* From the Transactions of the American Society of Civil Engineers.

they are sorted for straightness. A portion are then sent to the consumer, but a large portion are first coated with copper.

The process of forcing is proximately the same as that of moulding until the material is ready for the moulds; then, instead of being moulded, it is heated and made into cylindrical plugs, which are placed in a heavy iron cylinder, and, by means of a plunger driven by hydraulic pressure, the plastic material is forced through a steel-bushed orifice and comes out in the shape of a continuous cylinder, which is cut to the lengths desired. The carbons are then sent to the furnaces, and from this point the process is the same as for the moulded.

The forcing process permits of a wide range of shapes, as by changing the size of the steel-bushed orifice, cylindrical carbons can be forced having a diameter of $\frac{1}{16}$ in., and from this size up to or even above 4 in. in diameter. Many other shapes besides cylindrical can also be made, such as plates that are not much over 4 in. wide and of a thickness of from ½ to 1½ in. or over. These are cut into short lengths and used for dynamo or motor brushes. Plates as small as ¼ × ⅛ in. are also forced for small generator or motor brushes.

There is a great difference in density and structure between moulded and forced carbon. The pressure under which moulded carbon is made is about 8,800 lb. per square inch, while by the forcing process the pressure required is double or three times as great. By the method of forcing, the material is crowded together as it is pressed toward the small end of a conical chamber and is finally forced out at the vertex, thus giving a combination of lateral and end pressure.

By the method of moulding, the carbons receive side pressure only. Under the side pressure, the material tends to laminate in planes parallel to the axis of the carbon; while under end pressure, the planes of lamination are at right angles to the axis. As usually made, the pressure is not sufficient to produce distinct lamination; but it is evident that the structure of the material is inclined toward this class of formation, as in the case of slate rock, which is laminated in planes at right angles to the lines of pressure. Under certain conditions, lamination may be observed both in moulded and forced carbon.

Carbons as they are usually made for arc lamps are about $\frac{7}{16}$, ½ or ⅝ in. in diameter, by about 12 in. in length. In some cases pairs are used, a carbon 7 in. and one 12 in. usually constituting a pair. Besides those there are several other sizes in use; for searchlights and for many of the large lighthouses, carbons as large as 1½ in. in diameter and often larger are employed.

In addition to the ordinary pencils, many other forms may be moulded, such as cups or crucibles, or almost any design where the material can be retained in moulds and submitted to great pressure. Plates are made 12 to 14 in. square, and in thickness from $\frac{1}{16}$ in. to over 1 in.; and even larger sizes are often made.

In its physical properties carbon varies greatly, the variation depending upon its composition and treatment in the process of manufacture. The hardness may be from that of chalk to that of crockery, and its specific gravity may vary to about the same extent. It is quite brittle, and this property is retained through all its stages of hardness. The tensile strength and resistance to crushing increase with the hardness.

For cutting carbon the emery wheel is generally employed; it can be drilled or cut in the lathe with steel tools, but its effect is to wear them away very rapidly; even diamonds can be used as cutting tools but a short time. On the hardest specimens these operations are performed with difficulty even with the best of tools.

As applied to electrical engineering, the most important and interesting use of carbon is in the arc lamp; here we find phenomena that are wonderful even in the light of the most advanced science. If two ½ in. carbon pencils be placed with their points in contact and are included in an electric circuit having a current of 10 amperes, a slight amount of heat will be developed in the body of the pencils, which will be greatest at the point of contact; if, while the current is still passing, the pencils be separated a few millimeters, an arc of great luminosity and heat will be formed. If the poles of a voltmeter be connected with the pencils, the voltage due to the resistance of the arc will be seen to vary directly as its length, or nearly so; at about 20 volts the arc will be scarcely visible, and will increase in brilliancy and heat as the points are separated until the voltage reaches about 50, when the light will appear to be the most brilliant. At a point somewhere above this voltage, possibly 70 or higher, the arc will go out with a snap.

In the above case, if the current be maintained constant, of course the watts required will vary as the voltage, and this variation of the total watts is employed by all makers of arc lamps as a means of moving the feeding mechanism. This, in some lamps, may be so delicately adjusted as to move the carbons toward each other when the distance between the points has increased an amount corresponding to 1 volt, while many lamps require an increment of 5 volts to cause the feeding device to respond.

One of the most notable points in regard to the burning of the carbon arc is that the temperature in the positive carbon rises much higher than in the negative. It is noticed that when we extinguish the arc by turning off the current, the point of the positive carbon remains incandescent after the negative point has become black; the intensely heated crater formed on the positive carbon radiates far more light than the incandescent point which is formed at the end of the negative. The consumption of the positive is about twice as great as that of the negative when burned in the air; if burned in a vacuum, then the positive only is consumed. These facts seem to indicate that the larger part of the energy of the current is expended upon the positive carbon. A large part of the energy expended upon the arc is doubtless used in maintaining a counter electro-motive force, and another portion is absorbed in the conversion of solid carbon into vapor.

The arc may be colored by the introduction into the carbon of almost any foreign substance, and the color is characteristic of the substance employed, as in the case of the Bunsen flame; and as there are but few substances which are not volatile in the electric arc, the range of color is very large. The intensity of temperature is, without question, highest in the center or inner portion of the flame and lowest toward the outer circumference; for this reason the vapors of substances arrange themselves in concentric envelopes—those which volatilize at the highest temperature taking positions nearest the center, those which volatilize at the lowest temperature becoming the outer envelope.

The carbon flame affords one of the best subjects for spectrum analysis; it is therefore of great value for this purpose, and by its use the field of the spectroscope has been greatly enlarged.

It is perhaps important to note that, aside from the color effect of foreign substances in the carbon pencil, there is in most cases a reduction of the light and generally a lengthening of the arc; this may be accounted for on the supposition that foreign substances usually volatilize at temperatures lower than carbon, and hence supply vapors which radiate less light, and, volatilizing more rapidly, the quantity of the vapor is increased and a corresponding reduction of voltage may also be noted. If the foreign substances are not homogeneously incorporated with the carbon, the arc will be unsteady and the light will be unsatisfactory.

In the burning of arc lamp carbons, there is always a quantity of carbon dust that falls from the burning points; this is not a product of combustion, but particles of carbon, which are detached and thrown off from the highly heated points by calcination. Many attempts have been made by inventors to reduce or prevent the loss of life of carbons due to this cause. Some degree of success has been attained by introducing into the carbon ingredients which, fusing at a comparatively high temperature, become slag and mix with the detached particles and prevent them from falling off; and retaining them until they are consumed, the life of the carbon is prolonged to a very marked degree.

The hissing sound so frequently observed in the arc light carbons is a matter of importance. There seems to be a strong current of air and vapor moving between the highly heated points; when this current impinges in a certain manner against the point toward which it flows, hissing will be the result. To illustrate: if a jet of air be blown from a small tube, at high velocity, against a solid substance, a hissing sound will or will not be produced, depending upon the velocity of the air, the nearness of the solid and its configuration.

Many experimenters have endeavored to obtain a quiet, steady arc by the introduction into the carbon of foreign matter, which, by producing vapor more easily than carbon, will so modify the conditions as to prevent hissing; and, with a view of holding the arc in the center, a core is used. This core is simply a center, which may be $\frac{1}{16}$ in. or more in diameter, of a material that is different from the body of the pencil and contains more or less of the foreign matter.

Some of the most quiet and steady-burning carbons that are in use have been obtained by the use of foreign matter and a core. Carbons are also made with hollow centers, through which solutions of salts are simply poured, a sufficient quantity being left therein to produce the desired result.

As early as 1867 M. Carre coated carbons with metals, such as zinc and tin; and about the same time Mr. Joseph Van Malderon experimented with carbons electroplated with copper. Carbons have, therefore, been electroplated almost from their first introduction, and copper has been the metal used. The only reason the writer has seen assigned for this use of copper is that it reduces the resistance, conveying the current to the end of the pencil with but little loss of energy. The life of the carbon is increased by coating with copper from 8 to 10 per cent.

The total resistance of an uncoated pair of ½ in. carbons, in a newly trimmed lamp, is about 0·20 ohm, while the total resistance of the lighted lamp is about 5 ohms. It is evident, therefore, that the resistance of the carbons is about 4 per cent. of the total resistance of the lighted lamp. The resistance of the lamp coils may be 3 per cent. The decrease of resistance due to copper coating will not account for the increase of the life; this is due, in the writer's opinion, to the fact that the copper tends to support and retain the particles of carbon that are detached from the points by calcination; to some extent, also, the fused copper forms in liquid beads, and, by absorbing the calcined carbon dust, tends to prevent its loss.

A comparatively new use for carbon is found in the carbon brush for dynamos and motors; here carbon is substituted for the copper brush, and hence retains the name, which appears like a misnomer. Carbon brushes reduce the cutting of the commutator and the sparking to almost nothing. The same commutator may be used for years with carbon brushes which, if copper were used, would be worn out in a few months. The quality of the carbon brush is of great importance; it must be of fine texture, sufficiently hard, and should act in some degree as a dry lubricant, and it should not give a squeaking noise. These are points that can be provided for by the manufacturer. Much difficulty is sometimes experienced by heating. This, of course, is a question of conductivity, and can usually be remedied by making the brush larger, or by coating it with copper, or by doing both.

The telephone is indebted for a large measure of its great success to artificial carbon. Here its value depends upon the principle that an increase of pressure produces a decrease of resistance. The writer is inclined to think, with Mr. S. P. Thompson and others, that the increase of pressure simply makes a more perfect contact. As the resistance of carbon is higher than that of metals, it is, in some cases, an excellent material for this purpose, and especially where moderate resistance is required.

Among the advantages of carbon for electrical resistances, we may note the fact that it can be heated almost to a red heat and held at this temperature, without undergoing any change whatever; and, being practicably infusible, it will stand for a short time very high temperatures, even in the atmosphere, without suffering any deterioration. If held long at a red heat, however, in the air, it will calcine and sometimes oxidize. Carbon has also the remarkable property of showing a reduction of resistance as the temperature rises. At high temperatures this is very marked; for example: the decrease in resistance of an incandescent lamp filament at a white heat may be one-third of its resistance when cold. At temperatures below a red heat, however, the change of resistance is of comparatively little importance.

Some of the difficulties that attend its use as a resistance material are as follows: the resistance of carbon varies between wide limits; two carbon pencils ½ in. in diameter and 9 in. in length could be selected, of which one would have a resistance of 0·20 ohm and the other 0·07 ohm. The forced carbon being more dense is always lower in resistance than the moulded, other conditions being the same. The resistance, however, may be largely controlled by variations in the manufacture.

The connection between carbon and a metal conductor often becomes a troublesome point, especially if high temperatures are to be used. For low temperatures the carbon may be electroplated with copper and the metal conductor may then be soldered; but for high temperatures the connection must be made by some form of clamping device.

Carbon is not used as a resistance where calibrated resistances are required, owing to the difficulty of predetermining its exact resistance. For resistance purposes, carbon is used in the form of pencils as small as ⅛ in. in diameter; larger sizes are also used; it has also been used in the granular form and as a powder.

As a contact piece, where contacts must be made and broken frequently, carbon has a great advantage in many places over metals; and frequently, where metals are used in switches for contacts for large currents, carbon blocks are successfully used as a last point of contact. In such places as these last mentioned, carbon often gives a long arc, but even where one pole is metal, instead of burning the metal the current seems to expend its energy on the carbon, which suffers but little and is renewable.

Carbon is almost universally used in primary open-circuit batteries for the positive pole, and for this purpose it is made in the form of cylinders or plates. It is not acted upon at ordinary temperatures by any acid or other liquid known to chemistry, and in batteries it is easily depolarized. Carbon is also used, to a limited extent, for crucibles; and when mixed with clay, stands very high heats without oxidization.

It is remarkable that while carbon is made in variety of forms, its uses are almost entirely confined to electrical engineering; and as we note the rapid advancement of this new department of scientific work, we may also note, as one of the changes it has brought to our century, this new industry—the manufacture of carbon.

A slight idea of its growing magnitude in the United States may be gained from the fact that it claims an investment of over $1,500,000.

THE DISPOSAL OF THE GARBAGE AND WASTE OF THE WORLD'S COLUMBIAN EXPOSITION.*

By W. F. MORSE, New York City.

Two years since the report presented by the Committee of the American Public Health Association on the Disposal of Garbage and Refuse gave a clear idea of all the methods then in use for the disposal of city waste. Since that time the progress of destruction by fire has been by far greater than has been the employment of other devices. It is the purpose of this paper to briefly state what has been added to our knowledge on the subject, with special reference to the disposal by fire of the organic waste and garbage of the World's Columbian Exposition.

Total destruction by fire of city waste has been proved by six years' experience to be of great service to this country. So far as reports can be obtained, none of the garbage furnaces in use two years ago have been abandoned, but, on the contrary, the number has nearly doubled. New forms of destructors have been brought forward for experiment; novel ways of employing fuels are on trial; the utilization of the heat produced for obtaining power is found to be practicable; more convenient means for handling the material are used; the cost of operation is considerably reduced, and a general survey of the whole field shows a decided advantage both in number of furnaces constructed and their ability to perform the work required.

In Great Britain a still more rapid advance has been observed. From an exhaustive report to the City Council of Edinburgh made by a special committee, a paragraph may be quoted:

"There are now more than 310 cell destructors in use throughout the principal English towns, consuming 2,000 tons of refuse per day, at a cost varying from two and a half pence per ton at Bolton to three and a half pence at Southampton; nine pence at Ealing and Leicester, to one shilling at Derby, and one shilling three pence at Winchester."

It has been stated by competent authority that the present year there would be built in England 100 more cell-destructors, dealing with 250,000 tons of refuse per year. Thus, in Great Britain the process of destruction or disposal of town waste by fire has become a necessary part of the municipal sanitary work. No other new methods or devices appear to have been brought into use. There is a notable absence of the mention of any form of utilization of waste until the purification by fire has been first made.

Here at home there has been manifested a deep interest in this question; many cities and towns have sent out commissions for inquiry and examinations at places where various furnaces and process methods are employed, resulting in reports and recommendations for the erection of garbage furnaces. The individual yearly official reports of health officers have in a great number of instances included a concise description of garbage cremators, with estimates of cost of construction and operation, urging upon the attention of the city authorities the adoption of this form of waste disposal.

Perhaps the most instructive example of the disposal of waste by fire has been the work done for the past five months at the World's Columbian Exposition, and which is daily going on, affording an opportunity for a personal inspection of the value and sanitary usefulness of this means of getting rid of the "sins of the people."

When the plans for the World's Columbian Exposi-

* A paper read at the International Congress of Public Health, Chicago, October 11, 1893.—*From the Sanitarian.*

tion were completed and it was known that 600 acres of ground would be occupied, that a considerable part would be used as the permanent residence of persons who would be constantly on the grounds, and that for six months the buildings would be thronged by a vast multitude, it became evident that the sanitary care of this extent of ground and its inhabitants was one of the most serious questions before the administration.

Given a residential population of 30,000 to 40,000 and a daily average of 150,000 to 300,000 additional visitors, it was estimated that the excreta, garbage, refuse and waste of every kind that must result from their presence would be nearly 100 tons per day, all of which must be collected and disposed of within the bounds of the Exposition, there being no legitimate outlet on land or water for such a purpose.

It is doubtful, in the history of this or any other country, whether there has ever been a sanitary problem of equal magnitude which must be sölved in the short time allowed, or which demanded a more safe and scientific solution, than was the one here presented. To make a failure was to imperil the fortunes of the great enterprise, while a success meant not only protection for health, but the comfort and convenience of a great multitude of people.

After the adoption by the Exposition of the Shone hydropneumatic system of sewerage, the question of the final disposal of the product of the sewage sludge and the collection and disposition of the waste and garbage was considered. An exhaustive examination of all methods in use was made by the engineer in charge of the sewerage and water supply of the Exposition, Mr. W. S. MacHarg, of Chicago, resulting in the adoption of the Engle system of destruction by fire.

A contract was entered into with the Exposition authorities by the Engle Sanitary and Cremation Company, of Des Moines, Ia., and New York City, by which the construction of two garbage furnaces to destroy the sewage sludge, garbage, stable refuse, and miscellaneous combustible waste, was guaranteed by the company. The location assigned was a lot 150 × 75 feet in the extreme southeastern part of the grounds, near gate No. 6, and within a short distance of the Anthropological Building, the Forestry Exhibit, and near to the Sewage Cleansing Works, and here were built two Engle garbage cremators, placed together longitudinally, with a brick stack 50 feet high.

The details of construction of the Engle furnaces have been printed at length in the Proceedings of the American Public Health Association, and it will at this time be sufficient to summarize this for the benefit of those who may not have seen or do not recall the description. The cremators, including the stack and brickwork connecting with the furnaces, are 45½ feet long, 17½ feet wide, and 12 ½ feet high, exterior dimensions. On each side are platforms 21½ feet wide by 57 feet long, reached by an inclined aproach of 100 feet. The covering house is 35 feet square, of corrugated iron. There are large sliding doors on two sides, through which the garbage carts discharge their loads upon iron slopes leading from the platform down to the feeding holes of the furnaces. There are two of these slopes, which are 20 × 10 feet, and have a storage capacity of ten tons each. The garbage dumped from the carts passes down the slopes into the feeding holes, of which there are four for each furnace, one being large enough to receive the carcass of a horse. It falls upon the transverse grate bars in the upper or main combustion chamber. These bars are made of interlocked fire clay moulded blocks, firmly keyed together, with spaces through which the ashes fall into the lower chamber. The fires are at each end of the upper chamber, one being above and the other below the level of the grates. The main or primary fire is by the action of the draught brought directly over and through the material on the grates, driving the smoke, odors, and gases the length of the chamber and downward into the flame from the second fire. This perfected and complete combustion fills the lower chamber and space beneath the grate, and passes on its way over bridge walls to a second combustion chamber, and finally into the base of the chimney. Every particle of carbon, vapors, gases, and smoke is annihilated or transformed into carbonic acid gas, that is discharged at a temperature of 1,000° at the top of the chimney—a thin, colorless, invisible gas, which is immediately dissipated. Of all the chimneys and smokestacks within the grounds there is none which shows so little signs of burning fuel as does this one. Connected with the interior of the combustion chambers are inlets which bring hot air from small chambers over the fire boxes, to which the oxygen is admitted from the outside and heated to a high temperature. Hollow arches over the top, air spaces in the sides, and hot air pipes from the chimney also assist in furnishing heated air for the combustion of the garbage.

The distinguishing feature of the Engle system is the use of the second fire, destroying the products of combustion from the material burned and utilizing the heat thus obtained within the furnace. In the destructors employed in England this is accomplished by a secondary fire called a "fume cremator," placed near the base of the chimney, the heat from which cannot be utilized. Before the introduction of this device their chimneys emitted smoke and offensive odors.

The fuel used at the Exposition furnace is crude petroleum. This is brought by pipe lines directly from the oil fields in Indiana to tanks within the grounds, from which it is pumped into a stand pipe 30 feet high supplying all the power plants of the Exposition. To atomize the oil, power is obtained by a 12 kilowatt electric motor which drives a Root blower, giving an average pressure of 12 ounces of air per square inch of opening. The form of burner used is the S. C. T. burner, atomizing by air alone, using no steam. This burner, a late invention of Messrs. Squire, Cobb & Towl, is largely employed by the Standard Oil Company in its pumping stations and is the only example of its type in use at the Exposition. By an accurate test made by weight and measure of the oil, it is determined that under usual conditions there is used from 5 to 7 gallons of oil per hour by each burner; three burners being usually run in each furnace, the maximum amount of oil required would be from 30 to 42 gallons per hour, but this is greatly reduced during the latter part of the work, when, the radiated heat of the furnace being very great, less fuel is required.

There is brought to the cremators at 10 a. m. from 8 to 15 tons, the average quantity being about 10 tons of sewage cake from the Sewerage Cleaning Station. By the Shone system all the sewage from the grounds is forced by compressed air into large receiving tanks at the cleansing station, being about 2,500,000 gallons daily. After treatment with chemicals and the precipitation of solids to the bottom of the receiving tanks, the effluent is run off into the lake and the residuum pumped into sewage presses and formed into sludge cakes 2½ feet in diameter and 1 to 1½ inches thick.

These cakes come directly from the presses to the furnaces, being broken up into fragments in their transfer by carts. An analysis of this sludge gives moisture 58 per cent. and dry matter 42 per cent. Of this dry matter there is about 18 per cent. of combustible material, being 6 to 8 parts of oily or soapy material and 10 to 12 of paper pulp and fecal waste, the remainder being ash, lime, earth and chemical and mineral products. Thus only 18 per cent. of the original sewage bulk can be actually burned. When exposed to high temperatures in this semi-fluid, viscous condition, the liquids slowly evaporate and the residuum falls in a yellow powdery ash. It does not burn, as there is so small a percentage which fire can take hold of, but transforms to a condition like burned clay or earth. The ash remaining is far greater in quantity than from an equal amount of garbage, the process is slower, actual results showing that 24 tons of garbage can be burned at a lower temperature in the time required by 8 tons of sludge at a far higher heat.

The daily collection of garbage begins at 11 o'clock at night and continues until morning. The carts used are those known as the Hill garbage wagon, a light, water-tight iron body on two wheels, holding 45 cubic feet, with a projecting tailboard allowing the discharge of the contents free from the wheels. They are drawn by one horse and attended by one man.

The garbage comes from the kitchens of the national and State buildings, restaurants, the native villages, and often contains large amounts of coal ashes. There is no paper, sweepings or combustible refuse, and but small quantity of excreta from earth closets and vaults. There have been burned the bodies of two camels, four horses, two cows, two deer, one elk, several dogs and smaller animals. These pass into the upper combustion chamber through the large feeding hole, no preliminary cutting being necessary. The body of the largest horse was consumed in an hour, the smaller animals in much less time. There was no visible discharge from the chimney during their combustion. The mixture of coal ashes with garbage, which has sometimes been as much as 25 per cent. of ash, delays the process of combustion, requiring more time and labor to pass it through the grates, but does not otherwise affect the operation of the furnaces. The quantity of liquids contained in the garbage is very large. After rains there is always a great increase in this; frequently the carts discharge one-third or more of their contents in water.

There are required three shifts of four men each for the 24 hours, which, with two engineers and superintendent, makes 15 persons employed in the management of the furnaces. Because of their peculiar situation and the fact that the furnaces must always be ready for public inspection, a larger force is employed than would otherwise be necessary for the work. The greater proportion of the work is done between the hours of 12 o'clock midnight and 12 o'clock noon. It could be all done in the six hours from 12 to 6 o'clock a.m. if the collection could be brought to the furnaces more promptly. The cost of operation and maintenance, including the cost of fuel, is, as nearly as can be reckoned, from 60 to 70 cents per ton. This is larger than has been done at some other of the Engle furnaces, because of the exceedingly refractory character of the sludge destroyed. As before stated, it takes much more heat and labor to destroy the sewage sludge than it does a quantity of garbage three times its bulk, and the product of ashes and consequent labor in handling these is very largely increased. If the ordinary and usual collection of garbage of a city, say, for instance, Chicago, was to be destroyed by this process and the work carried on by private contractors or by strict oversight on the part of city authorities, it is certain that the cost of operation would be considerably reduced. It is safe to say that 50 cents per ton would represent the cost for this class of garbage. Where the garbage includes the miscellaneous combustible refuse of the city the cost of combustion is still further lessened, as every particle of combustible matter aids in consuming the wet material. For instance, at the city of Savannah, Ga., where there have been two Engle garbage cremators in use for the past four years, the official report of the operation of these furnaces from January 1 to September 1, 1893, is as in the following table:

The cost for destroying the 37,955 cubic yards is $4,457.21, at a net cost of $11\frac{71}{100}$ cents per yard. This does not include horses, cows, etc., which are burned in the cremators—this is garbage only. It is difficult to estimate this quantity by weight, as it includes a large proportion of combustible refuse and a considerable amount of the contents of privy vaults.

During the year 1892 the average cost per cubic yard for fuel and labor at this city (Savannah) was 13 cents.

Garbage loads	14,922
Cubic yards	37,955
Cows	97
Horses	155
Goats	30
Dogs	1,650
Cats	2,768
Fish	55 bbl.
Meats	7,675 lb.
Poultry	10,643 hd.
Onions	23 bbl.
Oranges	36 ld.
Bananas	31 ld.
Apples	5 bbl.
Infected goods	651 pieces.
Average amount burned daily	$158\frac{15}{100}$ cub. yds.
Average loads hauled daily	$62\frac{18}{100}$.

As will be seen, the addition to the city garbage proper of combustible refuse tends not only to provide means for the disposal of worthless matter, but to diminish the cost of maintenance of the furnace which destroys the offensive kitchen offal. This record is still further strengthened by reports of a similar character from the cities of Norfolk, Va.; Richmond, Va.; Jacksonville; Panama; Salt Lake City and Ogden, Utah; Des Moines, Ia.; Findlay, O., and many other cities where these furnaces are in use.

The ashes from the destruction of garbage at the Exposition accumulate in a pile outside the house and are used by the authorities of the Exposition in filling such parts of the grounds as had to be brought up to grade. No effort has been made to utilize them for any purpose of fertilization, but they possess undoubted value, as they contain from at least 4 to 6 per cent. of potash and a small percentage of phosphoric acid. Repeated analyses of the products of garbage combustion have shown that there is enough value in these ashes, if properly separated from the debris, to very nearly pay for the fuel used in the operation of burning. When used for filling low grounds or making streets they are more valuable than the same amount of earth or gravel. On sandy roads these ashes pack solid, do not break up under the wheels, and make an elastic and firm track.

The destruction of the garbage of the Exposition has been continuously performed since May 9, when one furnace went into operation. There has been no cessation; the daily collection being delivered and disposed of with the utmost rapidity consistent with the sanitary performance of the work, the object being to keep the grounds free from waste and to care for the sewage sludge as fast as produced, so that no offense shall arise, and there need be no large accumulation on hand. This has been perfectly accomplished; and had it been possible to secure a perfectly trained body of men to operate the furnaces, so that experienced help would be sure of being had at all times, the work of operation would have been much simplified. Taking the work of these garbage cremators as a whole, considering the difficulties under which they were constructed, the limited extent of time for which they would be employed, the exceedingly refractory character of the waste to be consumed, and the difficulties incident to the construction, management, and superintendence of the work, the results accomplished have certainly been remarkably successful.

It must be remembered that this destruction is performed under the observation of men experienced in furnace construction—engineers perfectly familiar with all the details of application of heat and power, experts who are responsible for the cleanly condition of the grounds and the comfort of great multitudes of people—and is inspected by thousands of persons interested in examining, for sanitary reasons, the destruction of waste where the slightest sanitary annoyance would be instantly observed and commented upon. To have done this work five months to the entire satisfaction of the board of administration and the sanitary engineers of the Exposition is a most striking and conclusive evidence of the value of garbage cremation and of the usefulness of the Engle system when brought into use on a large scale. It is evident that the same work could be performed elsewhere under conditions which could hardly be more exacting with equal success.

There remains in this connection only one thing more to be noted: In most cities throughout the United States the collection service, whether by contract or by municipal work, collects and transports all the waste of the city in one receptacle. In but comparatively few places is the separation made of putrescible garbage, combustible waste and ashes. The result is an aggregation of material which cannot be destroyed in its original state, which is difficult to separate satisfactorily, and which is entirely worthless from the admixture of putrescible matter which permeates the whole.

The next step demands an apparatus which shall take this material and prepare it for cremation, separating the valuable parts and destroying the rest. It is entirely practical to so arrange a series of screens, sieves, or separative machinery which shall take the mixed garbage, ashes, etc., remove the finer portions of ash, separate the paper, leather, glass, iron, rags, and discharge the residuum into the mouth of the furnace, where it is destroyed. The material which is of value, and which is by this process sorted out, would then be disinfected by steam heat, cleaned and prepared for sale, and the revenue therefrom placed to the credit of the city. If the city of New York can receive $93,000 each year for the privilege of picking over the garbage as it is discharged on the decks of the scows, and if the parties holding this contract can make a large sum of money by this crude, imperfect system of handling this material, it is quite certain that if the work were carried on in a systematic manner a great deal larger revenue would be produced. What is true of New York is true to a greater or less extent in every city of the country. There is to-day hauled out and put upon the dumps, cast overboard, or discharged into garbage cremators, valuable material enough to defray 25 per cent. of the cost of the collection service in every place. Under the American system of wasteful living there is thrown out from households a large proportion of food products, which would be reckoned valuable abroad. Under the somewhat lax and irresponsible methods of municipal business conducted by committees and councilmen of this country, there is less attention paid to the economical operation of garbage disposal methods than should be done; the result is the destruction yearly of a great mass of valuable waste which should be saved at a profit to the city.

Another thing, the heat caused by the destruction of putrescible waste can be perfectly well applied for the production of power, which, in its turn, is used for municipal purposes. There goes up the chimney of every garbage cremator in the country heat enough to run a steam boiler of 15 to 40 horse power. When these garbage destroyers are built as they should be, in connection with other municipal plants where steam is employed, the cost of operation would be greatly diminished, and the necessity of doing the work cleanly and economically will become much more apparent. Our English brethren have made greater progress in this direction than has been done in this country. Their destructors in some cases are self-supporting, from the fact that everything of value is utilized and

the heat is turned into active power. The day will come in this country when this will be as much a part of the disposal system as is the construction of the furnaces themselves.

THE DISPOSAL OF EXCRETA

without the intervention of conveyance by sewers is accomplished by the operation of a small fire closet which has been constructed and is at work at the side of the garbage cremators at the World's Exposition. This shows by a small working model what might be done on a larger scale in every school house, public building, or manufacturing establishment where no drainage can be secured and where the necessity for the disposal of the organic waste is evident. Proceeding upon the same plan of employing two fires, the one disposing of the excreta and the other the products of that combustion, the excreta is received upon the grate bars, the liquid portion passing into the pan underneath, and at the proper time—usually twice each month—is destroyed by the application of fire in the two fire boxes. The amount of fuel is insignificant, the time required very short, and the operation of destruction inoffensive, unobjectionable and sanitary. This device has been employed in this country for six years, has been found to be a perfectly sanitary substitute for all privy vaults, system of water carriage or earth closets, and is susceptible of being applied at every place where the conditions do not warrant the conveyance of household excreta by drainage. This apparatus will repay a strict investigation and will demonstrate its usefulness under all conditions.

A RECAPITULATION

of the work done at the Exposition up to date may be of interest, though it is necessarily incomplete.

For the five months that the cremators have been used there was about 5,732 tons of sewage cake and garbage brought to the furnaces, also a considerable amount of stable refuse and damaged food products, besides the bodies of 12 large animals. The average weight of a load of sludge cake was found to be 2,700 pounds and of a load of garbage 2,035 pounds. In these calculations the weight of sludge is assumed at 2,400 pounds and of garbage at one ton, except in the middle of the summer, when this was slightly larger.

The largest quantity of oil burned in one hour was 71¾ gallons, used by 6 burners, the average of eight days' test being 37½ gallons per hour, or 6¼ gallons for one burner per hour.

One day's trial, during which time the oil, sludge, and garbage were accurately weighed, showed there was destroyed 8$\frac{1}{10}$ tons sludge cake, 27¼ tons of garbage mixed with large quantities of liquid, the time required being nine hours for the sewage cake and twelve hours for the garbage.

There were burned 895 gallons of oil for fuel. The labor employed extended over the twenty-four hours, the relative proportions of expense for fuel and labor being about 75½ cents for sludge, 67½ cents for garbage per ton.

Taking the cost for fuel and for labor during the time the furnaces were actually operating, the expenses would be considerably reduced, the increased cost being due to the peculiar conditions of night collection of garbage, the necessity for quickly destroying it, and the lapse of time before the sewage cakes are received.

The largest day's work done was the disposal of 21¾ tons of sewage cake and 38¼ tons of garbage, the time required being about eighteen hours, at a cost for fuel and labor of 60 cents per ton.

Finally, it will be seen that the disposal of city waste by fire can be carried on in the immediate vicinity of dwellings without nuisance or offense, provided the work be done by furnaces adapted to the purpose, and operated by men who are competent. It is demonstrated that not only garbage, refuse, and dead animals, but also sewage sludge and excreta can be perfectly destroyed when required. It has been shown that the cost of doing this work is as reasonable as can be expected, considering the difficulties which are to be encountered, and that this cost is steadily being reduced as the character of the work becomes better understood and the furnaces are constructed on more scientific plans. It must be evident that a great saving can be made by separating such valuable parts of city waste that can be sold, and thus diminish the cost of operation, and it is certain that the progress made in the direction of waste disposal by fire far outstrips and exceeds all other methods or means which have been developed since the meeting of this association held two years since.

Since the date of the foregoing paper (October 11, 1893) the record of work done has been brought down to the end of the Exposition. There have been burned in six months' continuous service the garbage and sewage sludge resulting from the presence of 27,250,000 persons. This work has been appreciated by the authorities and recognized by the award of medals of the highest class for the garbage cremators and the Engle fire closet.

THE MOON'S FACE—A STUDY OF THE ORIGIN OF ITS FEATURES.*

By G. K. GILBERT.

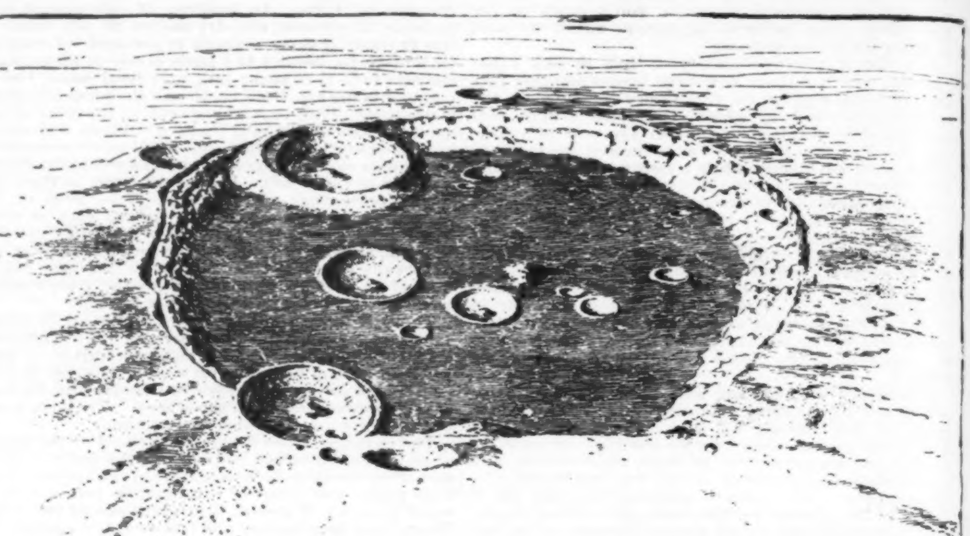
THE face which the moon turns ever toward us is a territory as large as North America, and, on the whole, it is perhaps better mapped. As its surveyor, even if armed with the most powerful telescopes, is still practically several hundred miles away, his map does not represent the smallest features; but as all parts are equally accessible, and as he has labored industriously these many years, there is no remaining space on which to write the legend "unexplored." Upon his map are a score of great plains with dark floors, which he calls *maria;* there are a score of mountain chains; there are a few trough-like valleys remarkable for their straightness; there are many thousand circular valleys with raised rims, which it is convenient this evening to call craters,* although for the purpose of detailed description he has found it convenient to give them many distinctive names;† there are thousands of bright streaks, which are neither ridges nor hollows, but mere bands of color; there are many hundred narrow linear depressions, which he calls rills.

Despite the persistent enthusiasm, the patience, and the industry with which he has studied his field, it must nevertheless be admitted that he has rarely satisfied himself and never satisfied his fellow-workers with the explanations he has suggested as to the origin of the features his map delineates. But selenographers are not the only students of the moon's face. There are also selenologists who use the telescope comparatively little but cogitate much, and who have evolved theories of great ingenuity and variety. Far be it from me to say aught to their disparagement, for this evening I join myself to their ranks; but, again, it must be confessed that the selenographers do not look upon the teachings of the selenologists with favor. So, despite all that has been done, the field of theory is still open, and this is my excuse for putting forth ideas founded neither on protracted observation‡ nor on protracted study—this and the further plea that the problem is largely a problem of the interpretation of form, and is, therefore, not inappropriate to one who has given much thought to the origin of the forms of terrestrial topography.

Crater Characters.—In the study of lunar physiography—or physiognomy, if you prefer—interest naturally centers in the craters, for these are the dominant features. All theories begin with them; and, before examining the theories, it will be well to place clearly in view the characteristics of the lunar craters. The range in size is great, extending from a maximum of about 800 miles diameter to a minimum of less than one mile. The size of the smallest ones is not known, as they are beyond the present power of the telescope. Within this range are several varieties, more or less correlated with size, but their intergradation is so perfect that they are all regarded as phases of a single type.* Those of medium size will be first described.

Picture to yourself a circular plain ten, twenty, fifty or one hundred miles in diameter, surrounded by an acclivity which everywhere rises steeply but irregularly to a rude terrace, above which is a circular cliff likewise facing inward toward the plain. This cliff is the inner face of a rugged, compound, annular ridge, composed of shorter ridges which overlap one another, but all trend concentrically. Seen from above, this ridge calls to mind a wreath, and it has been so named. From the outer edge of the wreath a gentle slope descends in all directions to the general surface of the moon, which it is convenient to call here the outer plain. The outer slope of the crater may be identical in surface character with the outer plain, or it may be radially and somewhat delicately ridged, as though by streams of lava. The inner slope, from the base of the cliff to the margin of the inner plain, is broken by uneven and discontinuous terraces, which have the peculiar habit of land slip terraces as one sees them about the flanks of a plateau capped by a heavy sheet of basalt. From the center of the inner plain rises a hill or mountain, sometimes symmetric, but usually irregular and crowned by several peaks. From the outer plain to the base of the wreath the ascent is 1,000 or 2,000 feet, and the ascent thence to the top of the wreath may be as much more. The descent from the wreath to the inner plain is ordinarily from 5,000 to 10,000 feet, and the height of the central hill is 1,000 to 5,000 feet. With rare exceptions, the inner plain is several thousand feet lower than the outer plain.

The central hill is not universally present, but appears in rather more than half the craters of medium size. With craters more than 100 miles in diameter its occurrence is comparatively rare, and it disappears altogether before the maximum size is reached. Increase in size is also accompanied by atrophy of the wreath, but to this rule there is a conspicuous exception, in that the greatest of all the craters preserves the third part of its wreath. In the absence of the wreath there is no sharp line of demarkation between the craters and the maria, and several large plains of



LUNAR CRATER CLAVIUS, SHOWING GROUPING OF CRATERS.
Diameter 143 miles; depth about two miles.

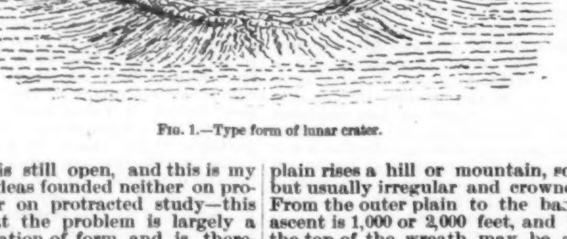


FIG. 1.—Type form of lunar crater.

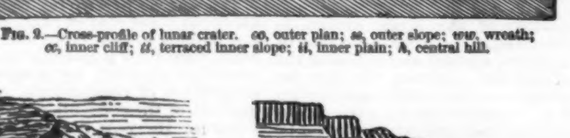


FIG. 2.—Cross-profile of lunar crater. *oo*, outer plan; *ss*, outer slope; *ww*, wreath; *cc*, inner cliff; *tt*, terraced inner slope; *ii*, inner plain; *h*, central hill.

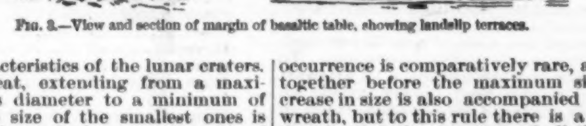


FIG. 3.—View and section of margin of basaltic table, showing landslip terraces.

* Address as retiring president of the Philosophical Society of Washington, delivered December 10, 1892. A supplementary communication on the same subject was made to the society at the meeting of January 7, 1893. The substance of that communication, as well as the results of later studies and experiments, are included in this publication.

An outline of the discussion was read to the National Academy of Science in November, 1892, and was reported in abstract in the American Naturalist, vol. 26 (1892), pp. 1056, 1057. A similar outline was presented to the New York Academy of Science in February, 1893, and is reported in abstract in vol. 12, pp. 93–95, of the Transactions. The same abstract appeared in Astronomy and Astro-Physics for March, 1893, No. 113, p. 286.

* The word *crater*, derived from the Greek name of a kind of bowl, is used chiefly to designate the bowl-shaped cavities of volcanoes. In this paper, as in most selenographic writings, it designates a topographic form without implication as to the origin of the form.

† Nelson classified craters as crater cones, crater pits, craterlets, craters proper, crater plains, ring plains, mountain rings, and walled plains, recognizing gradation between them and also between walled plains and maria. The Moon and the Condition and Configuration of its Surface, by Edmund Neison. London, 1876.

‡ My observations were practically limited to two lunations in August, September and October, 1892, a period affording eighteen nights available for work. My instrument was the 26½ inch refractor of the United States Naval Observatory, and the power found most serviceable was 400.

* The only exceptions to the type that I have noted are associated with certain of the rills. They are so small that I could not determine their characters with certainty, but they seemed to lack rims and to be hopper-shaped.

Neison (op. cit., p. 66) describes "crater cones" as of different type, characterized by cups at the apices of cones, but these I did not succeed in discovering. On several occasions I saw at the terminator what appeared to be small craters perched on high pedestals, but when the same objects were observed at such distance from the terminator as to escape the exaggeration peculiar to that illumination, they were seen to be depressed craters of the usual type.

oval outline, originally named as maria, are now classed with the craters.

The inner plain is a constant feature with craters of maximum and medium size, but disappears as diameter diminishes. It is rare with diameters of less than five miles. The central hill also is obsolescent downward, but persists farther than the inner plain. To my eye the interiors of most craters under four miles and of all under two miles appear as simple cups.* The

FIG. 4.—Varieties of lunar craters as related to size. The uppermost sketch represents the form of the smallest craters, the lowermost the form of the largest.

wreath of small craters is correspondingly small and is apparently a simple ridge, but it does not disappear. The depth of crater varies with the width, but less rapidly, so that the small have less absolute but greater relative depth.

The craters are more abundant in some regions than in others and there are comparatively few upon the maria. Usually the small craters are far more numerous than those of medium size, but in certain districts well covered by craters those of small size are less abundant. The craters overlap one another with every conceivable relation, except that the overlapping is never reciprocal. It is in every case possible to distinguish the newer from the older, the older being partially effaced by the newer. Small craters occur on all parts of larger ones, not excepting the wreath and the steep inner slope.

Volcanic Theory.—By the majority of writers the craters are assumed to be volcanic, and as they differ in size, abundance, and form from terrestrial volcanoes, it is thought that they represent some special type of volcanism determined by physical conditions peculiar to the moon. Let us compare the lunar and terrestrial craters and see how far their differences can be explained as dependent on differences of physical condition.

Take first the difference in abundance. Faye estimates the number of visible lunar craters, of all dimensions, at 20,000 to 30,000. There is no equivalent area on the earth so well explored as to admit of a close estimate, but a general idea may be derived from our knowledge of North America. From personal observation of the principal volcanic districts in Utah, Nevada, Arizona, and New Mexico, I estimate the number of craters and ruins of craters in those States and Territories at 1,000. In the remainder of our Western mountain region there are probably 500 more; 500 may safely be ascribed to the districts of similar geologic type in Alaska and British Columbia, and 1,000 to Mexico and Central America; giving as an estimate for the continent 3,000 craters, or one-tenth of Faye's larger estimate for a lunar area of similar extent. Our estimate includes only the craters formed at so recent a date that the processes of erosion and deposition have neither demolished nor buried them; but the geologic record shows that there have been volcanic eruptions in all ages, and indicates as probable that every district has been at one time or another a field of volcanic activity. Had the terrestrial craters of all periods been exempt, like those of the moon, from atmospheric and aqueous attack, it is easy to imagine that they might now be equally abundant.

In comparing the sizes of craters on moon and earth, it is impossible to consider general averages, because the size of the moon's smallest is not known; there is so great a multitude close to the limit of telescopic vision that we can readily believe there is another multitude beyond. Only the maxima can be compared. The largest known terrestrial crater has a diameter of about 15 miles; the largest lunar crater, that whose rim is partially preserved in the Carpathian-Apennine-Caucasus chain of mountains, had a diameter of 800 miles. The ten largest terrestrial craters of which I have record have a mean diameter of 11 miles;† the mean for the ten largest lunar craters is 275 miles.* The ratio of the largest is as 53 to 1; the ratio for the ten is as 25 to 1. The import of these ratios is materially modified by considerations arising from the laws of gravitational attraction. Taking into account the relations of the moon's mass and radius to the earth's mass and radius, it is computed that downward attraction at the moon's surface is only one-sixth as great as at the earth's surface. Bodies of the same size and material weigh only one-sixth as much on the moon; a bomb projected with the same energy or initial velocity would fly six times as far, and a cliff of the same material may stand six times as tall; so a lunar crater, if produced in the same way, may be six times as broad or deep as a crater on the earth without exciting our wonder. Applying the factor 6 to the ratios just cited, we reduce them severally to 9 : 1 and 4 : 1.

FIG. 5.—Diagram showing the relative diameters of the ten largest terrestrial craters, E, and the ten largest lunar, M. The lunar diameters are divided by six. The diameters are represented by the distances from the vertical line at the left to the short vertical lines.

To these ratios, considered as obstacles to the acceptance of the volcanic theory of lunar craters, three comments are pertinent:

1. The individual terrestrial diameters on which the second ratio is based are closely grouped near their maximum (Fig. 5), as though constrained by a limiting condition; the individual lunar diameters are widely scattered near their maximum, like the distances of aberrant shots from the bull's eye. Reasoning from these facts of distribution, we should predict that the complete exploration of the earth will bring to light other craters about as large as those now known, but will discover none much larger; but we could not make a similar prediction as to the maximum crater on the opposite side of the moon.

2. The conditions affecting volcanic action in the earlier geologic periods were doubtless different from those determining the size of the craters we can examine.

3. The material of the moon may differ from that of the earth's crust in such way as to affect the size of volcanic craters.

In vertical dimensions there is no important discrepancy. Lunar craters of the first rank range from 8,000 to 15,000 feet in depth; terrestrial, probably from 2,000 to 4,000. Dividing the lunar measures, as before, by six, we obtain 2 : 3 as the ratio of lunar depth to terrestrial; but as few terrestrial craters have been measured, this result cannot claim high precision.†

The contrasts as to form are of greater importance. To set them forth fully it is necessary to give separate consideration to several types of terrestrial craters. These may be called the ordinary or Vesuvian, the Hawaiian, and the maar types. Craters of the Vesuvian type—and these include nineteen-twentieths of all terrestrial volcanoes—are formed of lavas containing a considerable amount of water, and usually result from extravasation and explosion in alternation. As the lava rises in its conduit the contained water is converted into steam, by which the lava is torn to fragments and thrown into the air. That which falls back into the vent is again thrown upward, and that which falls outside the vent builds the crater rim. From time to time drier lava wells up and overflows the rim, or else forces a way to the surface at some lower level. In this manner there is accumulated a conical mountain with a funnel-shaped cavity at the top. Eruption is not continuous, but is interrupted by periods of quiescence, and sometimes, after a long interval of quiet, operations are again initiated by a great explosion of steam, the upper portion of the cone being blown out and an immense cavity left in its place. Eventually the reissue of lava builds a new cone inside the great crater, and this cone, which always carries a crater at top, may grow so as to bury completely the wreck of the great explosion.

With the forms resulting from this process, or alternation of processes, the lunar craters have little in common. Ninety-nine times in one hundred the bottom of the lunar crater lies lower than the outer plain; ninety-nine times in a hundred the bottom of the Vesuvian crater lies higher than the outer plain. Ordinarily the inner height of the lunar crater rim is more than double its outer height. The lunar crater is sunk in the lunar plain; the Vesuvian is perched on

FIG. 6.—Crater of Vesuvian type, without central cone. Features due to erosion are omitted.

a mountain top. The rim of the Vesuvian crater is not developed, like the lunar, into a complex wreath, but slopes outward and inward from a simple crest line. If the Vesuvian crater has a central hill, that hill bears a crater at summit and is a miniature reproduction of the outer cone; the central hill of the lunar crater is entire, and is distinct in topographic character from the circling rim. The inner cone of a Vesuvian volcano may rise far higher than the outer; the central hill of the lunar crater never rises to the height of the rim, and rarely to the level of the outer plain. The smooth inner plain characteristic of so many lunar craters is either rare or unknown in craters of Vesuvian type. Thus, through the expression of every feature the lunar crater emphatically denies kinship with the

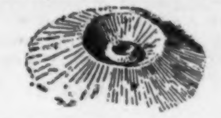


FIG. 7.—Crater of Vesuvian type, with central cone. Features due to erosion are omitted.

ordinary volcanoes of the earth. If it was once nourished by a vital fluid, that fluid was not the steam-gorged lava of Vesuvius and Etna.

Craters of the Hawaiian type are produced by lavas containing so little moisture that its conversion into steam does not cause violent explosions. Successive eruptions, flowing from the orifice in different directions, build by their congelation a massive cone with crater at top. In the intervals between eruptions the lava stands in the crater as a pool or lake, the liquidity of which is maintained by a circulation through the conduit or superheated lava from below. If the circulation slackens, a crust forms over the lake, giving the crater an inner plane like those of the moon. If the current is more active, the molten lava remelts part of the lava of the cone, undermining the walls of the crater and causing them to fall in, whereby the cavity and the lake are enlarged. Partially fallen fragments of the crater wall constitute terraces of the landslip type. Sometimes the lava retreats downward after crusting over, and fragments of the crust, adhering to the crater walls, form terraces of another type. Craters of this sort are somewhat rare, but their

FIG. 8.—Crater of Hawaiian type. Features due to erosion are omitted.

rarity does not affect their value as interpreters of extra-telluric phenomena. As long ago pointed out by Dana, they resemble the moon's craters much more closely than do those of ordinary volcanoes. They agree with lunar craters in the possession of inner plains, and to a certain extent in the terracing of their inner walls. They differ in the fact that they occupy the tops of mountains; in the absence of the wreath; in the absence of the central hill, and usually in the presence of level terraces due to the formation of successive crusts. In my judgment the differences far outweigh the resemblances, and I have not succeeded in imagining such peculiarities of local condition as might account for the divergence in form.

The maars are of still rarer occurrence, and represent the antithetic phase of volcanism. The process of their formation includes no eruption of lava, but merely an explosion of steam. By that explosion a body of rock is broken into fragments and thrown outward. Such of the fragments as descend outside the cavity are heaped about its margin, constituting a rim, which is smooth if the fragments are small and rugged, and irregular if they are large. Less than fifty craters of this type are known, and they are all small, the largest being less than two miles wide. They resemble the craters of the moon, in that their bottoms are depressed below the general level, and in that the volumes of their rims are approximately equal to the capacities

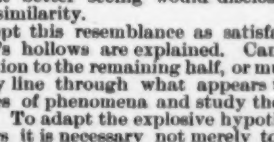


FIG. 9.—Crater of maar type.

of their cavities. They lack the wreath, the inner terraces, the inner plain, and the central hill. Thus characterized, they differ widely from the lunar craters of medium and maximum size, but they resemble those of smaller size. It is possible that the resemblance depends in part on the invisibility of minor features of the small craters of the moon; but it is perhaps equally possible that better seeing would disclose yet other elements of similarity.

If we accept this resemblance as satisfactory, half of the moon's hollows are explained. Can we adjust the explanation to the remaining half, or must we draw an arbitrary line through what appears to be a continuous series of phenomena and study the two parts separately? To adapt the explosive hypothesis to the larger craters it is necessary not merely to think of a greater explosion, but to imagine some phase or accompaniment of explosive action which will furnish the rim with a system of concentric ridges and the cavity with a level bottom and a central eminence. If the attempt at adaptation fails, as I think it must, then the explanation can be accepted for the small craters only by divorcing them from the large—and, whether it be accepted or not, inquiry must be continued.

Before passing to the examination of other theories, it is well to bring together the results of our inquiry into the adequacy of the volcanic. The comparative abundance of lunar craters is readily accounted for without prejudice to the theory. Their greater maximum width, though partly referable to a gravitational factor, constitutes a real difficulty, especially as volcanoes appear to have a definite size limit, while lunar craters do not. Form differences effectually bar from

* I am conscious that as the limit of telescopic vision is approached, the details of craters must disappear before the craters themselves are lost, and am therefore anxious to have this observation verified by those who are able to use higher powers than I could.

† 1. The old crater containing Lake Bombon, Isle of Luzon, is mapped (Reclus) as 16 × 14 miles in extent. 2. The crater of Asosan, Isle of Kiushiu, Japan, is 15 miles across (Milne). 3. Scrope mentions a "circular crateriform lake, about 15 miles in diameter," in northern Kamchatka (Volcanoes, 2d ed., London, 1862, p. 457). 4. An imperfect crater cirque on Mauritius, mentioned by Charles Darwin, is mapped (Admiralty) as about 15 × 11 miles in extent. 5. The crater walls surrounding Lake Bolsena, Italy, are mapped as 11 × 9 miles across. 6. The extent of the crater containing Lake Maninju, Sumatra, is mapped (Reclus) as 15 × 7 miles. 7. The extent of the explosion crater of Pepandayan (Junghuhn, cited by Scrope) is 15 × 6 miles. 8. The ancient crater of Teneriffe has a smaller diameter, variously cited as 7 and 8 miles and variously mapped as 7 and 10 miles. The larger diameter exceeds the smaller by 40 per cent. 9. The crater of Deception Island (S. Shetland) is mapped as 8 × 7 miles in extent. 10. The basal rampart of Monte Cavo, Italy, is 7 miles across. Certain maps indicate a basal rampart, 9 miles across, about Mt. Marindin, Isle of Mindanao, and a similar rampart, 10 miles across, about Mt. Askja, Iceland, but confirmatory literature has not been discovered.

* Apennines, Serenitatis, Crisium, Humorum, Humboldtianum, Bailly, Iridium, Clavius, Otto Struve, and Grimaldi. I have some doubt as to the propriety of including Mare Humorum, and less doubt as to the omission of Mare Tranquilitatis and Mare Fecunditatis. The mean diameter of each crater was used in the computation.

† The greatest measured depth of a terrestrial crater with which I am acquainted is that of the cup holding Crater Lake, Oregon—4,000 feet. Pichincha has been estimated at 3,000 to 4,000 feet. The general depth of the lunar crater Theophilus is 15,300 feet (Ebert).

consideration all volcanic action involving the extensive eruption of lavas, whether dry or saturated with water. They also exclude the maar process (single explosion) as an explanation of medium and large craters, but not as an explanation of small craters. The volcanic theory, as a whole, is therefore rejected, but a limited use may be found for the maar phase of volcanic action in case no other theory proves broad enough for all the phenomena.

(*To be continued.*)

GAS ANALYSIS BY SOUND.

A NOVEL method of analyzing mixtures of two gases of different densities has been brought under the notice of the French Academy of Sciences by M. Hardy. It depends upon the application of sound vibrations; and the apparatus is called by its inventor a formenophone, because it is primarily designed for the purpose of determining the proportion of formene, or fire damp, in the air of coal mines. This appliance consists of two organ pipes, of exactly the same dimensions, and giving out the same note when blown with air under ordinary conditions. If one of these pipes is filled with normal air, and the other with air containing say 1 per cent. of marsh gas, and the pipes are then sounded, the unison is disturbed, and one beat is heard every three seconds. With 2 per cent. of marsh gas in the air, there are three beats in two seconds; with 3 per cent., two beats per second; and so on. Similar results may be obtained when carbonic acid gas is the added impurity. M. Hardy gave figures of determinations with organ pipes sounding C_4. For mixtures having a density closely approaching that of air, pipes sounding C_3 are more suitable. Each determination is the work of a few seconds; and the inventor believes the apparatus to be of great practical value for the analysis of suspected air taken from mines or other inclosed spaces. It is interesting to note, in connection with this communication, that the phenomenon upon which M. Hardy's method is based is a well-known concomitant of organ performances in concert halls or churches where the air is liable to marked carbonic acid pollution through lack of proper ventilation. At the close of a crowded assemblage in such places the organ pipes give quite a different pitch of sound from that with which they began.

PROPERTIES OF DIAMONDS.

MOISSAN has given the results of an investigation to determine the temperature at which diamonds begin to burn in oxygen, these temperatures being measured by means of a thermoelectric couple. As the temperature is slowly raised, the combustion takes place slowly and without the production of light, the only evidence of it being the effect produced by the issuing gas on solution of baryta. At about 40° to 50° above this slow combustion temperature, the burning becomes rapid and a distinct flame is visible. The eight different specimens examined gave results as follows: Yellowish-brown carbonado burned at 690° with flame; black carbonado at 710°—720° with flame; transparent Brazilian diamond at 760°—770° without a flame; cut diamond from the Cape at 780°—790° without a flame; Brazilian bort at 790° without a flame and at 840° with a flame; Cape bort at 790° without a flame and at 840° with a flame; very hard bort at 800° without and at 875° with a flame. The harder the diamond, as a rule, the higher its point of ignition. Heated in hydrogen to 1,200° Cape diamonds do not lose weight, though they may lose their transparency and become lighter in color. At this temperature dry chlorine and dry hydrogen fluoride have no action on them. The vapor of sulphur attacks them only at 1,000°; but with carbonado, carbon disulphide is produced at 900°. The vapor of sodium has no action at 600°. Iron at its fusing point attacks the diamond readily and graphite separates on cooling. When heated with alkali carbonates at a high temperature the diamond is rapidly dissolved with evolution of carbon monoxide but no hydrogen. Hence it cannot contain hydrocarbons.—*C. R., Amer. Jour.*

UNIVERSAL POLYMERISM OR POLYSTERISM.

By HENRY WURTZ, Ph.D.

ALL intelligent metal-workers know that metals vary in their qualities according to the special treatment and handling they receive. The same principle, as can be proved, applies to all bodies whatever, both solid and liquid.

Chemists have in very recent years begun to give some attention to these internal transformations through external causes. Sterry Hunt, Walthere Spring, of Liege, and the eminent metallurgist Roberts-Austen may be mentioned as examples, among others. The present writer wrote of it as long ago as 1875, in a memoir entitled *Geometrical Chemistry*, which will be found, in abstract, in the *Am. Chemist*, March, 1876. Being during that year in continual association with Sterry Hunt, at the Philadelphia Exposition—both being members of the international groups of judges, we discussed these things extensively, and Hunt has approximated in some of his later writings to the views of the present writer as to the universality of "polymerism." In books published by him just before his lamented death, such as his "New Basis for Chemistry," and others, he has made it the main foundation of his theories. Before 1876 he seemed to the writer to share the usual view of chemists and mineralogists, that each distinct chemical element and compound should possess a distinct, definite and characteristic specific gravity, and that the variations of the figures obtained by different experimenters were due to impurities, errors of manipulation, differences of temperature, and other incidents more or less vaguely assumed. As to errors, this notion is wholly inadmissible. For chemists, the names given below will suffice to disprove this. With due skill and care—without which these men never worked—there is no difficulty in obtaining, *with the same material*, density figures agreeing even to the third place of decimals, or certainly to half the second place, and more especially with heavy metals. And chemists of this class never, or very rarely, work on any but chemically pure bodies.

The main object of the writer in preparing this table, has been to demonstrate conclusively to workers in metals the fact of the liability of the materials they work with to these variations in density, and thus lead to introduction into their minds of novel ideas on this subject. It may lead some practical men to study for themselves the modes of producing such variations at will, accompanied, as they must be, by corresponding variations in all the other qualities of the metal. It should be repeated, that this is a branch of chemistry which the writer believes to be as universal, as fundamental, and as important as any other whatever, and which has been hitherto unappreciated, and therefore ignored and neglected, almost universally by chemists.

It would have been interesting to add to this table, were it not probably too long already, some of the commoner chemical *compounds*, such as occur, for example, as pure crystallized substances obtained from solutions and otherwise, and which also show variations, sometimes even to a greater extent than the metals. This was probably for the first time pointed out in 1852 by the German chemist Kremers, who proved, among other things, that sodium sulphate (common Glauber's salt), when crystallized at 158° F., showed the density 2·654, but when at 212° F., showed 2·684. Others have obtained it as low as 2·462 and 2·597 and as high as 2·73. Some years later, two French chemists, Favre and Valson, obtained similar and larger variations with many other salts. As aforesaid, however, it is but very recently, but little before this present decade, that the general attention of chemists has been at all attracted to this subject; and there are still many who retain the ancient faith in the supposed *accidental* causes of variability of determinations of density of both elements and compounds, and in the inherence in every pure chemical body, or every *admitted* "polymere," of a characteristic and invariable density.

Evidence has been also introduced into this table to show that the true principle of universal "polymerism" is quite as marked in *liquid* as in solid bodies, so that it is not due to a mere change of mechanical structure. Organic bodies, of both liquid and solid forms, show it quite as plainly. Some gaseous and vaporous bodies probably show it also. But these must constitute future subjects.

"Polymerism" is a vague and wholly unsatisfactory term. It merely means "of many parts." The writer desires to displace it by the term *polysterism*, which means "of many volumes." This has a direct meaning and a direct application to this universal chemical law. There are, moreover, several kinds of polysteres; but this cannot be made clear till after the issue of some yet unpublished investigations of the writer.

TABLE

of the minimum and maximum densities of the best-known elements of matter; by Henry Wurtz, Ph.D.

1. *Monads:*

		Densities.	
Sodium	min.	0·9348,	H. Davy, electrolytic.
	max.	0·99,	Kopp.
Potassium	min.	0·84,	Kopp.
	max.	0·8766,	Baumhauer.
Cæsium	min.	1·872,	Setterberg.
	max.	1·886,	Setterberg.
Silver, ingot	min., slowly solidified	10·1053,	Baudrimont.
	max.	10·511,	Holzmann.
Silver, wrought	min.	10·4476,	Baudrimont.
	max.	10·5665,	G. Rose.
Silver, melted	min.	9·131,	Playfair and Joule.
	max.	10·002,	Quincke.
Silver, native	mim.	10·38,	filiform, Church.
	max.	11·1,	cited by Dana.
Copper, ingot	min.	8·4525,	slowly cooled, Baudrimont.
	max.	8·958,	electrolytic cast, Dick (Percy).
Copper, wrought	min.	8·3912,	wire, Baudrimont.
	max.	8·9587,	hammered, Berzelius.
Copper, melted	min.	7·272,	Playfair and Joule.
	max.	8·217,	Roberts and Wrightson.
Copper, native	min.	8·838,	Lake Superior, Whitney.
	max.	8·962,	Brazil, Marchand and Scheerer.
Gold, ingot	min.	19·1,	Kopp.
	max.	19·4,	Lewis.
Gold, wrought	min.	19·207,	hammered, Elliott.
	max.	19·6,	hammered, G. Rose.
Gold, precipitated	min.	19·2981,	precipitated by oxalic acid, G. Rose.
	max.	20·6882,	precipitated by green vitriol, G. Rose.
Gold, native	min., 2·54 per cent. silver	18·43,	Forbes.
	4·0 " " "	18·77,	Awdejew.
	3·58 " " "	18·79,	Awdejew.
	4·0 " " "	18·89,	Awdejew.
	1·76 " " "	18·95,	Marsh.
	max., 0·16 " " "	19·099,	Rose.

It will be readily observed that the variations in gold bear no relation to the small proportions of silver present in the native gold.

2. *Dyads:*

Glucinum	min.	1·64,	Nilson and Petterson
	max.	2·1,	Debray.
Magnesium	min.	1·69,	Kopp.
	max.	2·24,	Playfair and Joule.
Calcium	min.	1·55,	Lies-Bodart and Jobin.
	max.	1·8,	Caron.
Zinc, ingot	min.	6·861,	Brisson.
	max.	7·21,	Daniell.
Zinc, melted	min.	6·48,	Roberts and Wrightson.
	max.	6·9,	Quincke.
Cadmium, ingot	min.	8·45,	Kopp.
	max.	8·75,	John.
Cadmium, wrought	min.	8·667,	Schroder.
	max.	9·05,	Children.
Cadmium, melted	min.	7·989,	Vincentini and Omodel.
	max.	8·394,	Quincke.
Mercury, liquid	min.	13·535,	Regnault.
		13·55,	Muschenbroek.
		13·584,	Balfour Stewart.
		13·603,	Schiff.
	max.	13·613,	Biddle.
Mercury, frozen solid	min.	14·0,	Kupffer and Cavallo.
		14·1932,	Mallet.
		14·4,	Regnault.
		15·19,	Joule.
	max.	15·745,	Hallstrom.

3. *Triads:*

Aluminum, cast	min.	2·5,	Wohler.
		2·56,	Deville.
		2·567,	Langley.
		2·6,	Deville.
	max.	2·607,	Langley.
Aluminum, wrought	min.	2·67,	Wohler.
		2·8007,	wire, Corbit.
	max.	2·8075,	foil, Bishop.
Indium	min.	7·11,	Reich and Richter.
	max.	7·421,	Winkler.
Thallium, wire	min.	11·808,	De la Rive.
	max.	11·91,	Crookes.

4. *Tetrads:*

Diamonds	min.	3·334,	North Carolina, Shepard.
		3·492,	Grailich.
		3·5,	Berzelius.
	max.	3·55,	Pelouze, also Brisson.
Graphite, purified	min.	1·802,	Lowe.
	max.	2·26,	Brodie.
Retort-carbon	min.	1·885,	Mene.
	max.	2·556,	Meyn.
Silicon, graphitoid	min.	2·001,	Winkler.
	max.	2·493,	Harmening.
Tin, ingot	min.	7·239,	Deville, quickly cooled.
		7·24,	Schertel.
		7·293,	electrolytic cast, Miller.
		7·373,	Deville, slowly cooled.
	max.	7·5565,	Herapath.
Tin, wrought	min.	7·292,	Spring, compressed.
	max.	7·3775,	Baudrimont, wire.
Tin, melted	min.	6·913,	Playfair and Joule.
	max.	7·144,	Quincke.
Lead, ingot	min.	11·1608,	Guyton de Morveau.
		11·235,	Deville.
		11·33,	Kopp.
		11·376,	Matthiessen.
		11·3888,	Karsten.
		11·44,	H. Rose.
	max.	11·445,	Berzelius.
Lead, wrought	min.	11·365,	Reich.
	max.	11·501,	Spring.
Lead, melted	min.	10·37,	Roberts and Wrightson.
		10·45,	Playfair and Joule.
	max.	11·07,	Mallet.

		Densities.	
5. *Pentads:*			
Antimony, ingot	min.	6·6101,	Breithaupt.
	max.	6·86,	Bergmann.
Antimony, melted	min.	6·528,	Quincke.
	max.	6·646,	Playfair and Joule.
Phosphorus, yellow	min.	1·77,	Berzelius.
	max.	2·09,	Bottger.
Phosphorus, melted	min.	1·744,	Playfair and Joule.
	max.	1·88,	Schrotter.
Phosphorus, amorphous	min.	1·964,	Schrotter.
	max.	2·106,	Schrotter.
Phosphorus, metalloidal	min.	2·148,	Troost and Hautefeuille.
	max.	2·34,	Hittorf.
Arsenic, solid	min.	5·28,	Playfair and Joule.
	max.	5·959,	Guibourt.
Bismuth, solid	min.	9·6542,	Karsten.
	max.	9·935,	C. Deville.
Bismuth, melted	min.	9·709,	Quincke.
	max.	10·055,	Roberts and Wrightson.
6. *Hexads:*			
Sulphur, orthorhombic crystals	min.	1·997,	artificial crystals, Bischof.
		2·0477,	artificial crystals, Spring.
		2·05001,	native crystals, Karsten.
		2·0788,	native crystals, Spring.
	max.	2·086,	native crystals, Dumas and Roget.
Sulphur, clinorhombic crystals	min.	1·868,	Bockmann.
	max.	2·072,	Mohs.
7. *Heptads:*			
Manganese	min.	6·85,	Bergmann.
	max.	8·03,	Bachmann.
8. *Octads:*			
Iridium, ingot	min.	21·15,	Deville and Debray.
	max.	22·38,	Matthey.
Platinum, ingot	min.	19·5,	Brisson.
	max.	21·5061,	Deville and Debray.
Platinum, wrought	min.	20·3,	Brisson.
	max.	22·069,	Balfour Stewart.
Platinum, sponge	min.	15·78,	Liebig.
		16·634,	Rose.
		21·169,	Playfair and Joule.
	max.	21·473,	Thomson.
Platinum, black	min.	17·776,	Playfair and Joule.
		20·7782,	Rose.
		22·8936,	Rose.
	max.	26·1408,	Rose.
Palladium, ingot	min.	11·04,	Cloud.
	max.	11·628,	Zincken.
Palladium, wrought	min.	11·8,	Wollaston.
	max.	12·148,	Lowrey.
Iron, ingot, almost carbonless	min.	7·883,	reduced by hydrogen and then cast, Caron.
		7·8707,	by fusing soft iron with iron oxide, Percy.
		7·922,	(0·14 per cent. carbon), Koppmayer.
	max.	7·93,	soft ingot, Elsner.
Soft wrought iron, almost carbonless	min.	7·6,	wire, Baudrimont.
	max.	7·868,	reduced by hydrogen and forged, Caron.
Iron, precipitated from solution	min.	7·5,	precipitated by zinc, Poumarede.
	max.	8·1393,	electrolytic, Smith (Percy).
Iron, reduced by hydrogen	min.	6·08,	Stahlschmidt.
	max.	8·002,	Schiff.
Nickel, ingot	min.	8·279,	Richter.
	max.	9·0,	Vauquelin and Hauy.
Nickel, wrought	min.	8·58,	Trautwine, rolled.
	max.	8·932,	Tourte, forged.
Nickel, reduced by hydrogen	min.	7·803,	Playfair and Joule.
	max.	9·261,	Rammelsberg.
Cobalt, ingot	min.	8·39,	Kopp.
	max.	9·152,	Gehler.
Cobalt, reduced by hydrogen	min.	7·718.	Playfair and Joule.
	max.	9·485,	Rammelsberg.

It is proper for me to acknowledge my indebtedness for a large proportion of the above figures to the magnificent Smithsonian Tables of Professor F. W. Clarke. Such figures have been carefully culled from this and from some other sources as would bring out most sharply the principles to be illustrated.

ANIMAL INTELLIGENCE.*

By Jas. Weir, Jr., M.D.

"Intelligence is a conservative principle, and will always direct effort and use into lines which will be beneficial to its possessor."† This definition of intelligence is peculiarly applicable to the lower animals, inasmuch as it does not convey any idea of a purely intellectual operation of the mind. Every instance of ratiocination in the lower animals has its origin in the fundamental principle of benefit to the animal evincing this faculty of reason. The words reason and intelligence are, in a measure, synonymous, for without intelligence, reason cannot exist, and *vice versa*—without reason there can be no intelligence. They are both psychic factors, dependent each upon the other. The lower animals do not evince a high degree of intelligence, yet high enough to lift the mental operation above the automatic and spontaneous action generally called instinct. Instinct itself is, in a certain sense, a process of intelligence, though its immediate operations may not be due to reason. Instinct involves mental operations; if it did not, it would simply be reflex action. It is heredity under a special name. The father transmits his mental peculiarities as well as his corporeal individualities to his son. The experiences of thousands of years leave their imprint on the succeeding generations, until deductions and conclusions drawn from these experiences become in man that psychic essence called mind. The lower animals pass through a like experience and arrive, each in his own sphere and degree, at a kindred mental destination.

Reflex action is simply muscular adaptation excited by appropriate stimulation without mental cognizance. Instinct has always a mental element; and the lowest animal that lives is no more governed by reflex action than is man himself. The action of a spider spinning her web is just as voluntary and is as much under mental direction and control as the action of a carpenter building a house. That the very lowest forms of animal life give evidences of intelligence can no longer be denied. A very common rotifer whose body is cup-shaped and whose tail is armed with forceps has been seen to seize a larger specimen with its forceps, and thus attach itself to its cup. The larger rotifer immediately swung itself violently about until it met a piece of weed, this it seized with its forceps and began "the most extraordinary movements, which were obviously directed toward ridding itself of its incumbrance." This it finally succeeded in doing, and the entire scene was so like intelligent action that the observer concludes "so that if we were to depend upon appearances alone, this one observation would be sufficient to induce me to attribute conscious determination to these microscopical organisms."* Conscious determination and ratiocination is found in animals as low down in the scale of animal life as the rhizopoda. *Aethalia* will confine themselves to the water in a watch-glass in which they are placed, but when the glass is placed on sawdust, they will leave the water and go to the dust—their natural habitat.† These rhizopoda are content to remain in water, as long as there is no sawdust in their vicinity, but as soon as they recognize the sawdust *through the glass*, they crawl over the rim of the latter to get into a more pleasing abode. This is a wonderful example of conscious determination to be found in an organism so low in the scale of life. Once, while examining some fungal cells, Carter saw a still more wonderful instance of intelligence in a rhizopod. He noticed that one of the spore cells had ruptured and that grains of starch were escaping from the crevice. Suddenly an *actinophrys* came into the field of vision and proceeding to the ruptured cell seized a grain of starch and then retired to some distance. Presently it returned to the same cell and extracted another grain through the crevice. "All this was repeated several times, showing that the *actinophrys* knew that those were nutritious grains, that they were contained in this cell, and that, although each time after incepting a grain it went away to some distance, it knew how to find its way back to the cell again which furnished this nutriment."‡ Oysters taken from a bank never uncovered by the sea open their shells, lose the water within and soon die; but oysters kept in a reservoir and occasionally left uncovered, learn to keep their shells closed and live much longer when taken out of the water.§ This is an act of intelligence due directly to experience, without even the factor of heredity. It is an instance of almost immediate adaptation to surrounding circumstances. One would not expect to find examples of animal intelligence in such a low order as the *Helicidæ*, yet several instances can be adduced where snails have not only shown ratiocination but also have evinced love and affection.

A gentleman fixed a land snail, with the mouth of the shell upward, in a chink of a rock. The animal protruded its foot to the utmost extent and, attaching it above, tried to pull the shell vertically in a straight line. Then it stretched its body to the right side, pulled, and failed to move the shell. It then stretched its foot to the left side, pulled with all its strength and released the shell. There were intervals of rest between these several attempts, during which, the snail remained quiescent.‖ Thus we see that it exerted force in three directions, never twice in the same direction, which fact proves conscious determination and no slight degree of intelligence. An observer, Mr. Lonsdale, placed two snails in a small and badly kept garden. One of them was weak and poorly nourished, the other strong and well. The strong one disappeared and was traced by its slimy track over a wall into a neighboring garden where there was plenty of food. Mr. Lonsdale thought that it had deserted its mate, but it subsequently appeared and conducted its comrade over the wall into the bountiful food supply of the neighboring garden. It seemed to coax and assist its feeble companion when it lingered on the way.* Here we see not only an example of memory and discrimination, but also of affection and solicitude. After the snail had made its voyage of discovery, with rare unselfishness and true affection, it remembered its sick mate and returned for it.

Beneath the pavement in front of my door a wasp (*Vespa nigra*) has her nest. The entrance to this nest is at the bottom of a *sulcus* formed by two parallel bricks. I rolled a piece of paper into a compact wad and placed it between the bricks and over the entrance during her absence. When she returned she seized the paper with her jaws and forelegs and endeavored to pull it away. This was prevented by the interposition of the brick on which she stood. She then went to the other side and tried again. Here she failed for the same reason. She then descended into the little gully between the bricks and easily removed the wad. When she again left the nest, I replaced the paper, and on her return she went through the same performance as at first. Again I replaced it, but the *third time she went at once into the gully and removed the obstruction.* This she did three times in succession. Comment is hardly necessary. The evidences of memory and ratiocination are too patent to be denied. Some members of another family, distantly related to the *Helicidæ*, the limpets, show evidences of intelligence, inasmuch as they have a very accurate memory of direction. Limpets, when at rest, live at certain fixed domiciles. When hungry, they leave these homes in search of food, but nvariably return to them as soon as they have satisfied their hunger. One very pointed instance of this homing sense is given by Hawkshaw, a most careful and exact observer. A limpet had made a clearing on a sea weed covered block of chalk. In the center of this clearing was a pedestal of flint which projected an inch or more. On the top of this flint pedestal the limpet had taken up its abode. The cleared space had several hollows where the animal could have easily sheltered itself, but it preferred to return to its exposed home after each of its excursions.†

Not many years ago, a French exhibitor with a trained company of fleas passed through the country. These insects had been taught to march and countermarch, to dance, to feign death, to pull miniature coaches, etc. While this does not evince voluntary ratiocination, it shows that fleas think and are capable of receiving instruction. "When we consider the habits of ants, their social relations, their large communities, and elaborate habitations, their roadways, their possession of domestic animals, and even, in some cases, of slaves, it must be admitted that they have a fair claim to rank next to man in the scale of intelligence."‡

When Lubbock says that the ant ranks next to man in the scale of intelligence he does not err. The superior intelligence of the ant has been recognized and commented on by man since the very inception of history. The wisest man of his day, King Solomon, uses the ant to point a moral. He considers her intelligence and industry worthy of emulation, and says to the sluggard: "Go to the ant, consider her ways and be wise." This one factor, intelligence, and the faculty of intercommunicating intelligently, makes a colony of ants a *perfect* society. Their social relations make it a model republic. Ants are true socialists: communists of an ideal type. Theirs is a patriotism sublimely grand in its total self-abnegation. The commonwealth is everything—individual weal is not considered. Man is susceptible to individual attachments which form the basis of his happiness. The affection of ants, on the contrary, is a patriotism that is extended to the whole community, "never distinguishing individuals, unless, as in the instance of the communal mother, connected with the furtherance of the common good."§ Ants can undoubtedly communicate. A short while ago I crushed a pismire in the track usually taken by the members of a colony inhabiting the hollow of a beech tree standing in my yard. A soldier ant came along presently and, smelling the blood of his murdered companion, was seized with a panic terror, and rushed away into the nest. He shortly returned with thirteen companions and made a slow and careful reconnoissance of the dead body and its surroundings. Then all of them examined the corpse, and, having satisfied themselves that their sister was dead, returned to the nest. In a few moments a large worker ant, accompanied by two soldier ants, came out, and, proceeding to the body, picked it up and carried it down the tree to the ground. They then went beneath the grass and I lost sight of them. Their every action seemed to me to be governed by an almost human intelligence. The discoverer of the murder hurried into town, gave the alarm, and, quickly gathering some of his companions, went out in search of the murderer. On discovering that their companion was dead and her slayer absent, they came back to town and sent out a burial party.

The ant is the only animal except man which has slaves and domestic animals. Their intelligence is so highly developed that they make a perfect success in rearing their cattle and in capturing their slaves. The cattle of the ants are of the order *Aphididæ*. The herdsmen of these aphidian cattle can be seen patroling the shrubs on which the aphides are grazing. On them devolves the care of the herds. They bring them out in the morning and carry them back at night. They gather the eggs of the aphides, carry them into a specially built nursery, attend them carefully until the young aphides are hatched out, and then carry them to the shrubs most liked by them for food. Some strange sense enables them to recognize one another—an ant of the same species, but coming from another nest, is immediately recognized as a

* From the *American Naturalist*.
† Cope: "Origin of the Fittest," p. 40.

* Romanes: "Animal Intelligence," p. 18.
† H. J. Carter: "Annals of Natural History."
‡ Ibid.
§ Dicquemase: *Journal de Physique*, vol. xxviii., p. 244.
‖ White: "A Londoner's Walk to Edinburgh," p. 155.

* Darwin: "Descent of Man," pp. 262-3.
† Hawkshaw: *Journal Linn. Soc.*, vol. xiv., p. 406.
‡ Lubbock: "Ants, Bees, and Wasps," p. 1.
§ Kirby and Spence: *Entomology*, "Perfect Society."

stranger and at once attacked. If the eggs of one ant colony are hatched out in another of the same species, the young ants are at once known to be strangers and intruders. This far transcends our intelligence. What mother could recognize her infant if it were born in the dark and she had never seen it? Again, if the *larvæ* of ants are removed, hatched outside of the nest, and then returned, the ants at once recognize them as kinsmen and receive them into the nest.* That ants and bees do communicate intelligently is no longer denied. Their means of communication is not definitely known, but it is the opinion of most scientists that it is through their antennæ.

I once saw wonderful evidences of this power of intelligent communication while watching a battle between *Lasius niger* and *Lasius flavus*. The black ants were on a foray, the booty in question being a large herd of aphides owned by the yellow ants. The yellow ants had a commissariat department and an ambulance corps. I frequently saw them drop to the rear during the battle and partake of refreshments. Those slightly wounded were also attended to by the ambulance corps. The black ants were in light marching order, and had neither of these conveniences and necessary adjuncts. These ants seemed to be governed by a high order of intelligence in this battle. The yellow ants repeatedly sent back to their village fo re-enforcements, and in this instance were victorious. They were not so fortunate, however, in a second battle I witnessed a short time afterward. Their antagonists were of the same species as in the first battle, but from a different colony. In this second battle the yellow ants were all slain, and their herds of aphides carried off by their conquerors.

The bee ranks next to the ant in point of intelligence, and I have witnessed numerous instances of ratiocination in these interesting little animals. My bee-house is built of brick, without windows, and has only one small door. The hives are made of glass and covered with thick curtains of muslin. This renders observation very easy. On one occasion I noticed that from some cause a comb had become detached and was in danger of falling to the floor. The bees had noticed this before it had become apparent to me, and had begun to provide against disaster. They rapidly built a broad, thick support of wax between the endangered comb and the one next to it, thus securing it firmly. They then reattached the detached comb securely to the roof of the hive. When this had been done, they took away the temporary support and used the wax elsewhere. When men see a wall out of plumb and in danger of falling, they use like methods to prevent disaster. De Fravière says that bees have a number of tones which they emit from the stigmata of thorax and abdomen and by which they communicate information.† When a bee arrives with important news she emits several shrill notes and taps a comrade with her antennæ; this comrade passes the news to another, this to another, and so on throughout the hive. If the news is pleasing all remains orderly, but if the news presages danger, great excitement arises. The news of danger is always carried first to the queen as the most important person in the community.‡ I have heard these tones and believe with De Fravière that bees communicate information in this way. The queen emits a tone which is different from those of the workers. When the queen makes a progress through the hive while laying eggs, she frequently emits this cry. As soon as the workers hear it they bow their heads and remain quiescent for several seconds. Both ants and bees show great affection for their young. They feed and cleanse them and assist them in every way possible. The young ant is shown all of the devious pathways and corridors in the habitation by the older ants, and her first visit into the world is made with several chaperones.

There is a spider peculiar to this locality (Daviess Co., Ky.) which I have never seen elsewhere and which I have not seen described. This spider spins two webs; one is a trap set for the procurement of her food; the other is built for the gratification of an æsthetic feeling hardly to be expected in an animal so low in the scale of animal life. This latter web is generally spun in the angle formed by two walls, and always where the early morning sun can shine on it for several hours. Through the center of the web, reaching from one extremity of its long diameter to the other, the spider spins a ribbon of silk about an inch broad. This ribbon is very beautiful. The mesh is as closely woven as silk itself, and shines in the sunlight like a band of silver. As soon as the sunlight falls upon this web, the spider makes her appearance and walks slowly up and down her glittering roadway. She is not at all timid, and I have watched her for hours at her strange performance. She irresistibly reminded me of some well-dressed woman who was out for a morning walk. She never left this ribbon to secure food, though I tempted her frequently with insects. After an hour or two of promenading, she would leave this web and go to her trap-web, which is generally situated near her place of amusement. This she kept up day after day until the duties of maternity called her elsewhere. I have never seen the male. There is but one other instance in the animal kingdom where an animal builds a special place of amusement. That animal is the bower bird, of which mention will be made further on.

Curiosity is largely developed in birds. The blue jay is the most curious as well as the most voluble of all birds. I have been able to differentiate twenty-three distinct utterances in the language, if I may use the word, of the jay. On one occasion, I left a glass jar containing three newts on a large block of sandstone in my front yard. It had not been there long before a jay flew down to examine it. One of the newts made a quick motion, and uttering a cry of surprise the jay flew to a tree overhead. He remained quiet for an instant, as if in profound thought. He then uttered his assembly call, and birds of all kinds came hurriedly flying up in answer to it. In a few moments I noticed in the surrounding trees, jay-birds, woodpeckers, sap-suckers, cat birds, song-sparrows, orioles, mocking-birds, blackbirds, peewees and flickers. They made a terrible outcry, but suddenly became silent, when the jay, which had called them together, flew down to the rock. Several of his most courageous brethren immediately followed him. He went up to the jar and made a careful examination of it and its contents, all the while uttering a low, querulous monologue. Suddenly he uttered three loud, peculiar cries and flew away. The assembly then dispersed. On another occasion I noticed a jay sitting silent and absorbed on the roof-tree of a grape arbor. He appeared to be watching something beneath him very intently. On focusing him in my glasses, I discovered that he was in a state of great excitement and trembling all over. I noticed the direction of his gaze and soon saw the object of his regard. A large male cat was stalking a hare and was just crouching to make his spring. He sprang at the hare, but his jump fell short, and the hare bounded away in safety. And then the jay-bird seemed to be fairly overcome with delight. He trounced himself up and down, screaming with sarcastic laughter. He seemed to be jeering and ridiculing the cat to his fullest extent, and the cat seemed to understand him. He dropped his tail and disappeared in the bushes. The jay uttered one last note of derision and then flew away.

I once saw a very young cockerel come up behind an elderly hen and suddenly embrace her. When she discovered the youth of her assailant her surprise, indignation and wrath was perfectly apparent and very laughable. Birds show a distinct individuality in nest building. No two pairs of birds, even of the same species, build nests alike. To the casual observer they appear alike, but to the careful and experienced nest hunter there is a marked originality in each nest. The general forms are the same, but each pair of architects leaves the impress of individual genius on their particular nest. Three pairs of cardinals have been nesting in my garden for several years. If shown the nest, I can tell the pair of birds which built it. Wallace gives an instance of original nest building. Several pairs of bullfinches were taken to Australia when quite young. When they came to build their nests, they built them totally unlike those of the English bullfinch. They were long and round, like those of the oriole, only the entrance was at the bottom.* Some birds have developed æsthetic feeling and have a well-marked love for the beautiful. Certain humming birds decorate their nests with beautiful pieces of lichen which they fasten on the outside. Feathers and various colored mosses are used for the same purpose.† Darwin asserts that the curious structures of the bower birds are pleasure houses built by the birds for their own amusement and sports.‡ These bowers are not nests and are never continuously occupied by the birds. The nests are built in the jungle some distance from the bowers. The birds first build a platform of sticks and twigs, all of the knots and short twigs being turned toward the ground, thus giving a perfectly smooth floor. The bower, an oblong, oval structure, open at both ends, is then erected on this platform. This is also made of twigs, with all projections turned outward. The entrance to this bower is decorated with feathers, bones, shells, mosses and, in fact, any gayly colored article which the bird can procure. Evidences of intelligence in the higher orders of animals are so patent that even the most casual and superficial observer can see them. The cat, the horse and the dog are nearer to man in his daily life than any other animal, and instances of their intelligence are very numerous.

I present here a letter of Mr. J. Gibson Taylor, Owensboro, Ky., in which he relates a remarkable instance of ratiocination in a dog: "The dog, a water spaniel, had gone after a stick flung upon the ice of a pond about twenty feet distant from shore. The water was about five feet deep. The ice gave way. The dog went under the water several times in swimming about the enlarged space made by attempting to regain the surface of the ice which gave way under his weight. He became thoroughly chilled by much confused swimming about in a circle, seeking some point at which the ice would bear his weight. I reached a limb to him, and calling him by name, shortly got his attention. He placed his paws upon the ice and seemed to listen intently as I extended the limb toward him, the ice, meanwhile, sinking under his weight as he looked at me. He caught the limb between his teeth and I assisted him by pulling him toward me upon the thicker ice inshore. Finally the ice became strong enough, about 15 feet from shore, to sustain his weight. So, still with his teeth locked on the stick, I pulled him on the thicker ice and across the surface to the shore."

Here the dog, fully seeing his danger, and understanding the purport of the stick thrust out to him by his master, grasped it with his teeth, and held on until he was dragged into safety. Could man do more or reason better?

*Lubbock: "Ants, Bees, and Wasps," p. 119 *et seq.*
† Romanes: "Animal Intelligence," p. 158.
‡ Ibid.

* A. R. Wallace: "Darwinism."
† Gould: "Birds of Australia," vol. i., p. 442.
‡ Darwin: "Descent of Man," pp. 92, 406.

WORKING HARVEYIZED ARMOR PLATE.

THE naval authorities are experiencing difficulty in preparing the Harveyized armor plates for use. Although the Harvey plate has beaten all others, as is generally conceded, it is a question whether the plates can be successfully fastened to the vessels without impairing their high efficiency. The Harveyized plates are so much superior in hardness to plain and nickel steel plates that the tools used heretofore are useless. The armor for the Maine has recently been supplied by the Bethlehem Company, but the constructors have not as yet discovered any feasible method of fastening on the armor without cutting out spaces and drilling to fasten the plates to the side. With the Harveyized plate the tools will do the cutting after the steel has been softened. It is believed that this local softening of the steel will weaken the steel so that its qualities will be reduced to those of nickel plate. Another point is also brought forward: the late Mr. Harvey received $96,000 for the right to use his process, and the department is also paying a royalty of one cent a pound for all Harveyized plate, so that the new armor plate is already very expensive and will be doubly so if certain parts require to be retreated. The matter is being investigated, and it is hoped that some method will be devised for putting on the armor plate without the necessity of an expensive operation which doubtless injures the value of the plate.

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